A McGRAW-HILL PUBLICATION

MAY 24 1930

Engineering News-Record

May 22, 1930

An Issue Devoted to Water Supply

Progress and Trends in Water Softening

By CHARLES P. HOOVER

Meter Installation and Operation Practice

By H. P. MATTE

Combating Corrosive Soil On a Twelve-Mile Pipe Line

By J. B. LIPPINCOTT and K. Q. VOLK

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Distribution Practice of Private Water Companies

By GEORGE W. BIGGS

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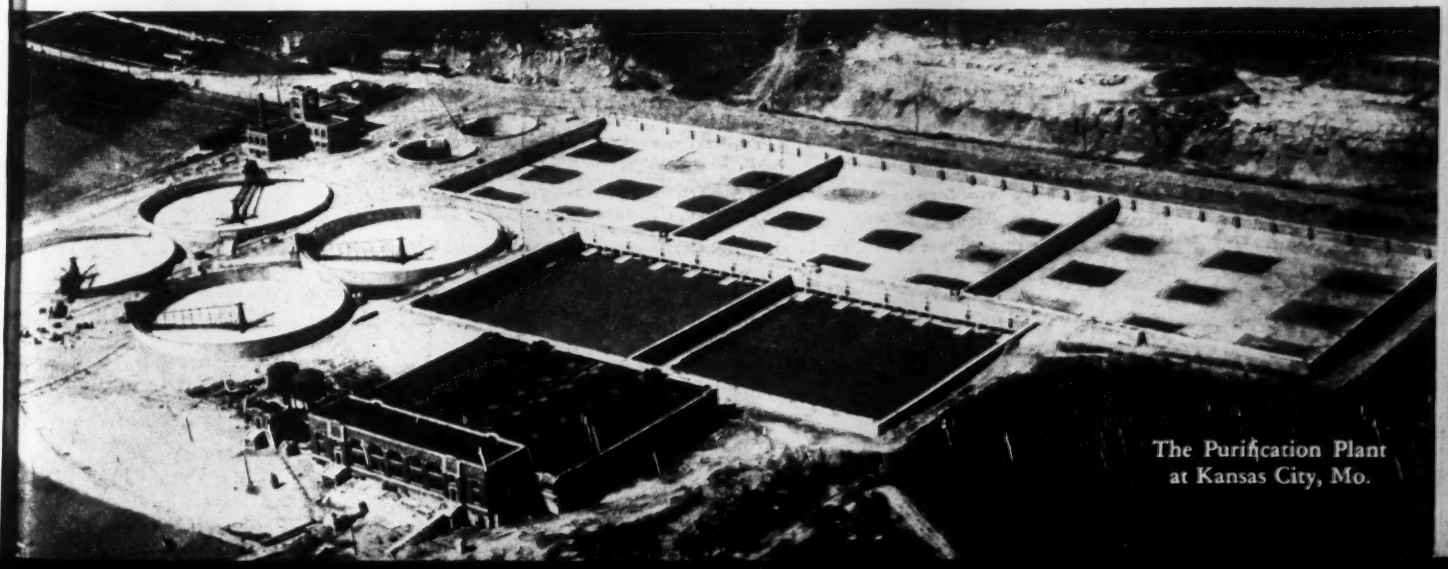
The Alexander Earth Dam Failure



The Purification Plant at Kansas City, Mo.

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ENGINEERING NEWS-RECORD

A Consolidation of Engineering News, Engineering Record, The Sanitary Engineer, and The Contractor

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American Water Works Convention

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CABLE ADDRESS: "MACHINIST, N. Y."

Published weekly. $5 per year. 25 cents per copy. Entered as second-class matter April 11, 1917, at the Post Office at New York, N. Y., under the Act of March 3, 1879. Printed in U. S. A.

Member A.B.C.
Member A.B.P.
NUMBER OF COPIES PRINTED THIS ISSUE, 32,025

NEW YORK District Office, 285 Madison Avenue
WASHINGTON, National Press Building
CHICAGO, 520 N. Michigan Avenue
PHILADELPHIA, 1600 Arch Street
CLEVELAND, Guardian Building
ST. LOUIS, Bell Telephone Building
SAN FRANCISCO, 883 Mission Street
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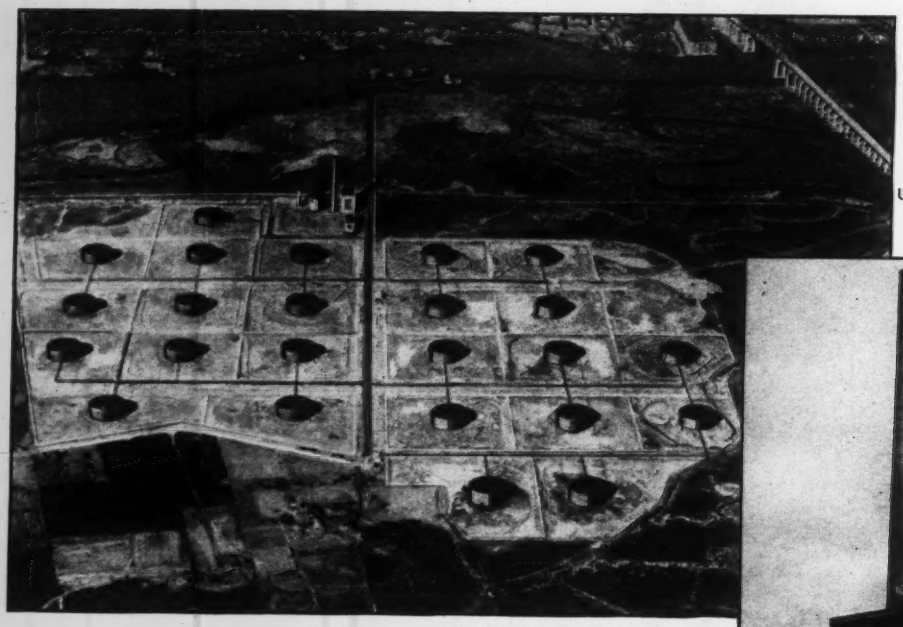
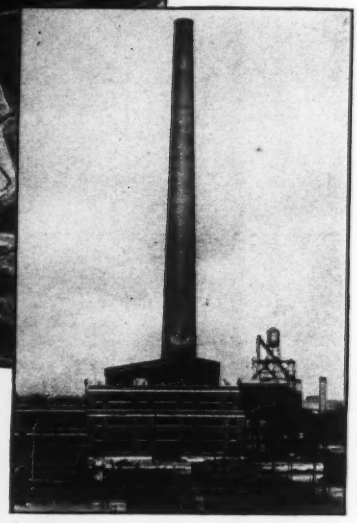


BULK STORAGE PLANT
Staten Island



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DEVOTED TO CIVIL ENGINEERING AND CONTRACTING

F. E. SCHMITT, *Editor*

Volume 104 NEW YORK, MAY 22, 1930 Number 21

An Issue Devoted to Water

THAT great branch of the civil engineer's art which concerns itself with the supply of water to civilized communities has won victories which place it high among the gifts of modern engineering to the human race. Even today its energy of development is so remarkable and its achievements so manifold as to go beyond the scope of weekly recording of detail. A perspective of major performances is therefore in order from time to time. It is especially appropriate at this moment, just prior to the gathering of water-works men at the meeting of the American Water Works Association in St. Louis—the same city in which the association held its first meeting, fifty years ago.

To this end the present issue is designed to constitute a survey of advance in the leading phases of present-day water engineering. Purification is in the forefront. Softening hard waters looms up as one of the larger activities of the immediate future. But meanwhile the current tasks of pipes, of distribution, maintenance and metering remain of an importance too great to warrant a lack of discussion. Water finance presents problems in another direction—and they are often of utmost seriousness. All these questions are discussed by high authorities in their separate subjects. Finally, detail discussion of engineering and administrative problems in the water supply of various cities are given, to typify the work in which the water-supply engineer is chiefly active.

Supplementing these articles, the first full account of the core failure of the Alexander dam in Hawaii is published in this issue. It is drawn from information obtained directly from the engineers in charge of the work. The vital importance of this accident to the art of building earth dams makes the account a matter of immediate concern to every engineer.

Water Purification Pre-eminent

IN THE front rank of water-works progress today stands purification. This applies alike to the firm establishment of fundamental principles, their application in engineering design and construction, and the number of people served with safe and agreeable water. Progress in water purification is all the more remarkable because its largest strides have been taken within the present century. In fact, most of the increase in population supplied with safe water, and most of the reduction in the waterborne typhoid scourge that disgraced hundreds of American cities in the first years of this century, was accomplished within the two decades just ending. And as a measure of that progress we may note that for some years past waterborne typhoid has been almost non-existent in American cities; only an occasional flare-up has occurred, minor in extent and inexcusable.

So far have we gone in the theory and practice of water-purification design in the last third of a century that of late progress has been characterized by few changes of a fundamental nature, though refinements have not been lacking. As Paul Hansen states in his appraisal elsewhere in this issue, the degree of stability in design is surprising. This does not mean that filtration practice has reached the dead flat of standardization, for every situation presents many questions which only judgment and years of experience can answer if economy and safety are to be attained. It does mean that the storm-and-stress period of water purification is over, and that we are able to assure safe water to all, at negligible cost. Let us glance at some of the steps that brought us to this fortunate position.

Prior to 1897 the efficacy of rapid filters was very uncertain. In that year experiments concluded at Louisville by George W. Fuller established rapid sand filters, preceded by chemical coagulation and sedimentation, as a purification means approximately equal in bacterial results to the older slow sand filters.

The first plant of characteristically modern reinforced-concrete design, with rectangular filters, as contrasted with the older wooden tub installations, was built at Little Falls, N. J., in 1902 by the East Jersey Water Company. All gravity rapid sand filter plants built since that time are designed in much the same manner as the Little Falls plant. No fundamental changes have been made; improvements are in detail.

Two factors stand out pre-eminently in the subsequent progress of water purification—namely, application of chlorine as a sterilizing agent, and acceptance of the U. S. Treasury standard for quality of drinking water on interstate carriers as a proper measure of the quality of filter plant effluents as well as of water not subjected to treatment.

During the first decade of its use, from about 1910 to 1920, chlorine was regarded as an additional safeguard and not as an adjunct necessary to insure an adequate degree of purity. More recently, and especially following the studies of H. W. Streeter in 1924, chlorination has been regarded essential to the objective of adequate bacterial purity.

Early standards of filter plant performance required merely a removal of 97 per cent of the total bacteria. Later this was increased to 98 per cent, and a limit of 100 bacteria per cubic centimeter was placed on the number that might appear in the filtered water. In 1915 the

first U. S. Treasury standard for purity of drinking water on interstate carriers was formulated. It was revised upward in 1925. The question at once arose whether this standard should apply to municipal water-purification works. There was much argument pro and con. Many sanitary engineers and filter operators maintained that, while the Treasury standard might be proper for a water of unknown origin, it was too rigid for a filter plant effluent because epidemiological evidence had proved a less rigid standard to be adequate. But in time the Treasury standard found virtually universal acceptance —in part, perhaps, because non-compliance bars a water supply from use on interstate cars and boats, but in part also because chlorine makes the standard readily attainable.

During the early part of the period dealt with in Mr. Hansen's article, great difficulty was experienced by sanitary engineers and public health officials in convincing the public of the necessity of purifying public water supplies to prevent disease. The public was also surprisingly indifferent to the physical characteristics of water. The past fifteen years has brought a great change. Not only has the sanitary safety of public water supplies come to be considered indispensable but demand has grown for what may be termed a perfect water—crystal clear, colorless, free from taste and odor, free from objectionable mineral content and practically sterile.

Progress in refining mechanical equipment has kept pace with the increasing demands of the people for a physically perfect as well as a hygienically safe water. Today the traveler may drink from the public water supply of practically any of our cities in safety. And the water is not only safe but attractive—with rare exceptions. Thus the ambitions of water engineers have almost reached complete fulfilment, as concerns principles. Yet putting these principles into practice will always require highly expert knowledge and judgment, to fit the available methods to the conditions at hand and to provide for increasing special needs, such as water softening. Undiminished opportunity remains for the work of the water-purification engineer; but on the present occasion it is gratifying to be able to record completion of the major achievement—the conquest of unsafe water and its sequelæ of disease and death.

Why Water Softening Lags

OF THE many public water supplies of the country that are excessively hard, only a small percentage are treated to yield soft water. Water softening is therefore largely an activity of the future.

Why does water softening lag so far behind clarification and disinfection as a practical art? One reason is public indifference, but a more serious cause is that, although the softening art is nearly a century old, it is still largely in the first stage of its progress, the commercial stage, where the manufacturers and supply men are more busily engaged in fighting each other than in advancing the art. Promoters of the use of softening materials and apparatus, and engineers as well, need only look back to the early days of mechanical filters to read a lesson.

The early builders of mechanical filters ruined themselves by multiplying variants in plants and details and companies to promote them, and by competing for business in terms of extravagant claims and unattainable contract guarantees. Consolidation followed, but that was not enough. It was not until a number of cities were wise enough to put water purification in the hands of engineers, chemists and bacteriologists—competent and disinterested men—that the task of getting bacteria, mud and color out of water was put on a sound engineering basis and a beginning was made of the marvelous progress which the art then experienced. When mechanical filtration was thus founded on able design and economical construction its supremacy over slow sand filtration was soon established. The methods of the rival manufacturers had never been able to accomplish this.

Both because cities have been slow to realize the advantages of softening and because they have concentrated first upon the more important problem of getting safe and clear water, they have not often given engineers the same opportunity to deal with hard water as with polluted water. Water purification has been furthered by liberal appropriations for working-scale experiment stations—a long succession from Louisville, Pittsburgh and Cincinnati on to the one now operating at Chicago. The time is near at hand when softening will receive similar aid. Though the lesson may not yet be sufficiently obvious to bring about immediate action by cities, there is all the more reason for the commercial interests in the softening field to co-operate both in the education of the public, as suggested elsewhere in this issue by A. M. Buswell, and in carrying forward an art in which so much progress has been made, as is indicated by Mr. Hoover's article.

Water softening has been practiced too long, and its fundamental principles are too well established and too easily applied without dependence on proprietary control, to be dominated by commercial rivalry. Special apparatus —parts if not complete plants—and vast quantities of softening agents will continue to afford large commercial opportunities. These will increase rapidly, now that the more vital and the more popular demands for safe and attractive water have been so largely met. In fact, in large areas of the country, what remains to be done in water purification, as ordinarily considered, can and will go on along with water softening.

With 90 per cent of the needed water softening still to be provided for, both manufacturers and engineers have large opportunities. To make the most of them in reasonable time, water softening needs to be put on as sound an engineering basis as water purification. That done, the lag between the two will be taken up with rapidity and to the benefit of all concerned—water consumers, engineers and contractors.

Water and Sewer Service

WHEN Hercules turned a river through the stables of Augeas to rid them of their thirty-year accumulation of filth, the singleness of the problem of water and sewerage was quite apparent. The problem still is single, but today we are apt to see it as two independent problems. Concentration on assuring clean and pure supply, and on removing from the used water the community waste gathered up in its passage, has put us in danger of regarding the two tasks as distinct instead of as one broad, general task—watering and cleansing a city.

Water supply and sewerage have more in common than is disclosed in the hydraulics, chemistry and bacteriology of our schools. Consulting engineers are aware of the interrelation of the two subjects, and offer their services impartially for either. Among the municipalities of the country, however, it appears that with but few exceptions the supply of water and its subsequent collection

and treatment are in the hands of separate groups of officials. Not only is this divorcement evident in administration but it is even more sharply defined in the methods employed to charge for the services rendered. Water-service charges are increasingly being based upon meter readings, but rarely is there a direct charge for sewer service, and still more rarely is the charge based on volume of sewage, though both the cost of conveying it to the point of disposal and the cost of treatment depend on volume.

Many vexing questions arise in an attempt to arrive at an equitable charge for the use of a sewerage system. The disproportionate costs involved in the treatment of industrial wastes, the general community benefits of sewerage systems for house wastes, and (in combined sewers) the relation of street drainage to sewer capacity, are complicating forces. But water-works managers have found ways to meet these problems. Some sewerage systems have been put upon an equally rational basis. Should not the same thing be applicable to all?

Study of the question here raised, in the light of local circumstances, may not in all cases point to sewer rentals. But in view of ever-increasing city tax rates and the difficulty in many cities of raising money for the collection and disposal of sewage the subject merits thorough consideration. Many engineers believe that sewer rentals or else water charges sufficient to cover sewerage costs are logical. In any event, it will be profitable to remember that all the water brought into a city for domestic and industrial purposes must be taken out, and that the costs of the two services are merely separate items of cost of a single, integral service.

Notes of the Week

Hydraulic Laboratory Approved

MORE than seven years of effort was crowned with success when President Hoover signed the hydraulic laboratory bill last week. In the near future the government is to build a great laboratory as part of the Bureau of Standards in Washington where problems of river and stream flow may be studied on a scale never before possible in this country. Much credit for the final passage of the legislation is due to John R. Freeman, the originator of the idea; to Senator Joseph E. Ransdell, of Louisiana, and to Engineering Council. Their persistence, despite many reverses, has kept the legislation alive until its chief opponent, the Corps of Engineers, was won over to giving its approval, thus assuring passage of the measure. Europe has had such hydraulic laboratories for years and it seemed inconceivable that this country with its many and varied hydraulic problems demanding study could long hold out against the establishment of one here.

Obstructing a Great Work

THIS week the President asked Congress to make an initial appropriation for building Boulder dam. The occasion makes it timely to record that less than two weeks ago the governor of Arizona made the preposterous charge of hasty action by the federal government in carrying the great project forward. Secretary Wilbur has replied in cogent terms. He points out that Congress in writing the statute authorizing the project set the date of Jan. 1, 1929, as the latest at which the lower states of the Colorado basin might by agreement influence the terms of the water and power contracts, but that the Interior Department waited nearly sixteen months after this date before signing contracts. If this be haste, let Arizona make the most of it! Secretary Wilbur also points out that he called a conference of the states affected in June, 1929; that in October he announced a tentative power allocation and price; that he held a hearing on Nov. 12, at which Arizona was not represented, although invited three distinct times; that on Nov. 14 and again on Dec. 2 he advised the governor, offering further opportunity for interstate agreement; and that the contracts, executed five months after this time, included special provision for the protection of Arizona's future interests, allocating to it 18 per cent of the total power with privilege of claim, relinquishment and reclaim. Lastly, he points out that the contracts assure Arizona an annual income ranging from $350,000 to $600,000 during the life of the contracts, aside from indirect revenue. The reply is full and conclusive. The false charge of hasty action is but another element of Arizona's consistent attempts to obstruct a great work, apparently with the sole objective of deriving fanciful royalties from the river's water resources.

The Alexander Dam Failure

THE more complete information given in this issue of the accident to the Alexander dam in the Hawaiian island of Kauai does not extend our knowledge of the causes of failure of hydraulic fill. One important point is made certain: The process of chemical consolidation of very fine material which was studied and applied in connection with the construction of the dam had no part in the failure, as it had not been used in those parts of the embankment which sloughed out. The novel chemical research which had been so well begun can therefore —and it is to be hoped will—go ahead with its progress unhampered by the handicap of having participated in a serious failure. There seems no other positive conclusion that can be drawn from the failure. The material was of a kind which has not been used in hydraulic fill in the United States but which has been used before in this method of construction in the Hawaiian islands. It was fine, but appears to have been well enough graded to settle in distinct core and beach zones, and the tests do not show that there was any notable deficiency in internal friction. The standing portions of both core and banks show by their vertical faces rather remarkable cohesiveness. Quite as fine material has been employed before and has remained stable; it is being used constantly in building Mississippi River levees. It would appear that any general conclusion to be drawn is the one that has many precedents in hydraulic-fill experience—deposition proceeded (either generally throughout the dam or locally in some portion) faster than consolidation went on and cohesion developed, and the result was an earth slide aggravated by a following discharge of impounded water and liquid mud. This is a lesson which bears on procedure in construction rather than on selection of materials and design of embankment. The Alexander dam failure, in brief, lies exactly in the category of the recent slide at the Saluda dam and of many previous movements of hydraulic fill in process of construction.

Wilson Avenue Crib, Chicago

Water-Works Intakes of the Middle West

Conditions to Be Met in Design, With Examples of Numerous Types in Successful Use for Many Years in Rivers, Lakes and Reservoirs

By Charles B. Burdick
Alvord, Burdick & Howson, Engineers, Chicago, Ill.

GIVEN A SOURCE of water supply, the next problem confronting the engineer who is designing a water-works is the intake. Standardization here is impossible, so many, so varied and so affected by local conditions are the factors involved. Long experience and wide observation qualify the author of the following article to write with authority on the subject. Although the intakes used as illustrations are in the Mid-West, the article as whole will be useful to designers of intakes in any part of the world.—EDITOR.

TO THE water-works man charged with the responsibility of maintaining a constant supply of good water, a long and costly experience has proved the value of utilizing the existing circumstances surrounding his intake to eliminate, as far as possible, unnecessary pollution, objectionable floating materials, sand that might score his pumps, ice or other substances that might block the intake. Thus the water-works intake becomes a problem worthy of careful study in the light of the conditions which surround it.

These conditions, all of which affect the type and details of the structure that must be built to give efficiency and permanence, may be summarized as follows:

(*a*) Source of the supply—that is, lake, pond, impounding reservoir or flowing stream.

(*b*) Nature of the place from which the water is drawn, including depth of water, character of the bottom, requirements of navigation, and violence of storms or floods that might change the character of the water or influence the permanence of the structure.

(*c*) Relation of the source of pollution to the location of the intake.

(*d*) Permanence or otherwise of existing conditions, particularly in so far as they would be affected by changing river bottom under floods and extreme low water.

(*e*) Necessity for special provision to prevent trouble from sand, leaves and larger floating materials, such as trees and logs.

(*f*) Prevalence of floating ice, ice jams or anchor ice.

(*g*) Physical surroundings that bear upon the desirable nature of the structure itself to insure its permanence, more particularly the character of the underlying bottom that must support the intake.

The wide variety of circumstances encountered in

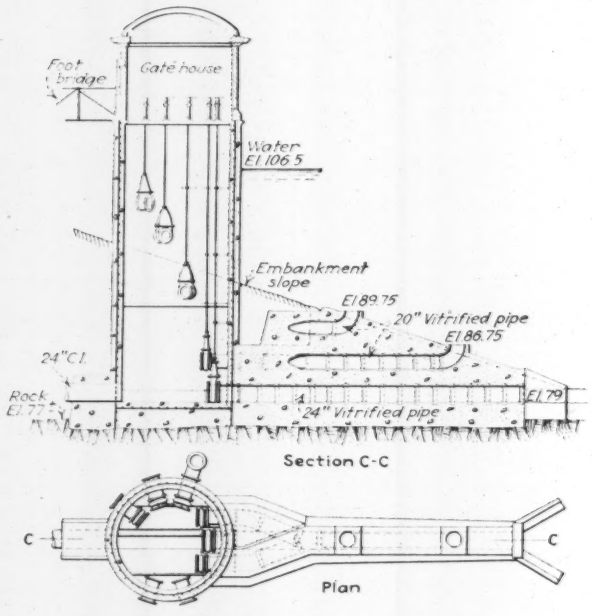


FIG. 1—RESERVOIR INTAKE BUILT AT TOE OF SLOPE
Illustrates way of drawing water from six levels into combined gatehouse and intake at Lexington, Ky.

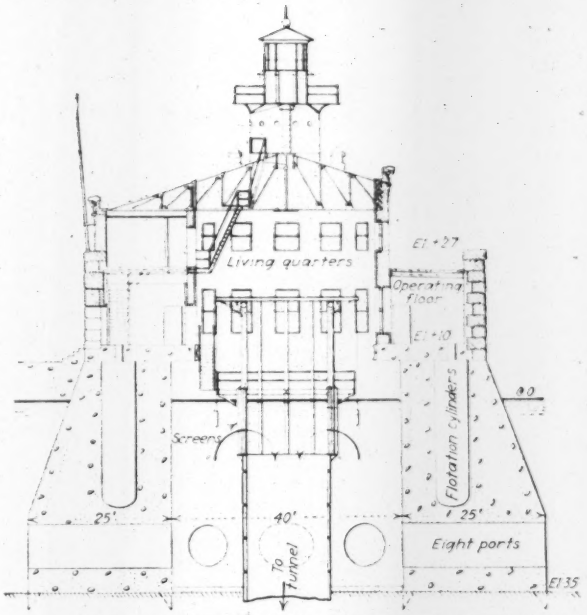


FIG. 2—LAKE INTAKE AT CHICAGO WITH LIVING QUARTERS

Maximum velocity of 1.1 ft. per second through intake ports. Continuity of operation insured by presence of crib keeper, particularly in winter

water-works construction explains in a measure why no two water-works seem to have exactly the same type of intake structure.

Intakes From Impounding Reservoirs—In the case of the impounding reservoir, which generally involves the draft of water at a place of considerable depth, the structures built are more or less similar.

If the dam is of masonry construction, a well is usually provided in the dam or its abutment at an accessible location, and is so arranged as to admit the water at several different elevations. This is desirable not only because the water surface in an impounding reservoir may rise and fall many feet but also because the quality of the water may vary for different depths at different times. It is sometimes desirable to draw water from near the surface and at other times from greater depths.

If the impounding dam is of earth, an intake tower is usually built near the inside toe in deep water. This tower is often connected to the dam by means of a suitable bridge, giving access to the gate-operating mechanism and the screens which frequently cover the intake openings. For small supplies the intake tower is often omitted and the inlet gates controlled by extension stems operated from the top of the dam. The intake of the Lexington (Ky.) Water Co. (Fig. 1) may be considered typical of impounding reservoir intakes.

Lake Intakes—The Great Lakes from Superior to Ontario constitute the largest body of fresh water in the world. They furnish an excellent water supply for a greater number of cities, large and small, than any other source of public water supply. A brief description of the types of intakes found to be most satisfactory will probably cover the most severe conditions to be met anywhere in drawing water from lakes and ponds.

In nearly all places throughout the Great Lakes system the underlying bottom is of moderately fine sand overlying blue clay. The sand stratum varies in thickness from practically nothing to 50 ft. or more. In its natural state the water is very pure, clean and moderately soft. Unfortunately, practically all the cities are located at the mouths of rivers entering the lakes, so that in most cases there is a tendency for the water for several miles from shore to contain sediment and sewage discharged by the streams. During violent storms the accumulated sediment for half a mile outward is churned up by the waves, making the shore water quite turbid. The worst conditions are created by an "on-shore" wind. When the wind is "off-shore," even if strong, the water is usually very pure and clear a few thousand feet from shore. During storms the sand on the lake bottom travels more or less at depths of less than 20 ft. and it is thus desirable to draw the water at a plane from 4 to 8 ft. above the lake bottom.

The water discharged by a turbid river may be compared with the smoke from a chimney. When discharged into a calm lake, it dissipates within a comparatively short distance from the mouth of the river. Under a brisk wind it often travels in a solid stream several miles from the river mouth. Cribs 4 miles from shore at Chicago frequently furnish water undesirably turbid for comparatively long periods. Generally speaking, the Great Lakes water cannot be regarded as satisfactory without filtration. Even with filtration it is desirable to minimize the sewage pollution and that intake site should be selected which receives the least pollution. When the physical difficulties have been overcome, which will be spoken of later, the question of how far from shore the intake should be located is largely a matter of a practicable load upon a purification plant and a financial balance between the expenditures for obtaining the water and the cost of its purification. Under modern standards for clean water, filtration is justified nearly everywhere, and questions as to distance from shore, except in the case of the largest cities, are usually governed by physical conditions.

Depths of 20 ft. or more are generally obtainable within 2,000 or 3,000 ft. from shore. Intakes in smaller

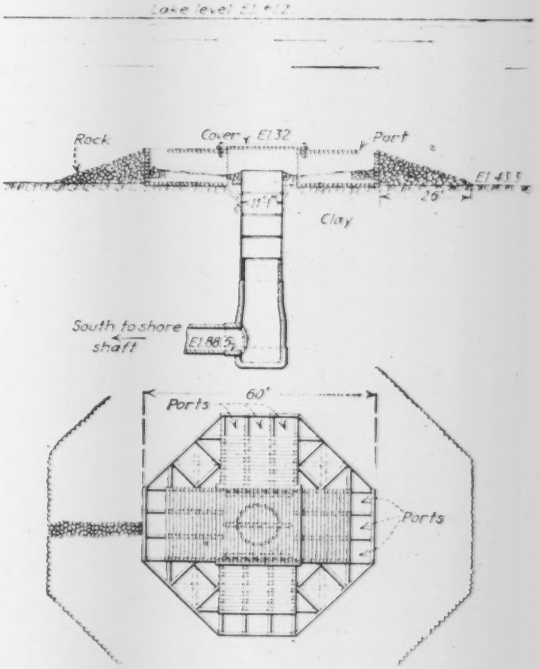


FIG. 3—SUBMERGED LAKE INTAKE FOR GARY, IND.

Crib has been in successful use for twenty years with no stoppage from ice.

depths are unsatisfactory on account of the movements of the sand on the bottom and because they are likely to be damaged by ice. In severe weather ice piles up in windrows as much as 10 ft. in height above the lake level and fills the shallow water almost solidly to the lake bottom. Such accumulations of ice may occur for from 500 to 1,000 ft. out from the shore, practically cutting off the flow of water shoreward. Thus it is desirable to locate such intakes in depths of not less than 20 ft., but 30 or 40 ft. is preferable and is secured by some of the intakes.

Surface Intakes—The larger cities, such as Chicago and Buffalo, find it desirable to take the water through surface cribs, with tunnels for delivering the water by gravity to the pumphouse shaft on shore. These cribs must be of considerable size and stability. They commonly take the water at comparatively high velocities through the intake ports and therefore rely for continuity

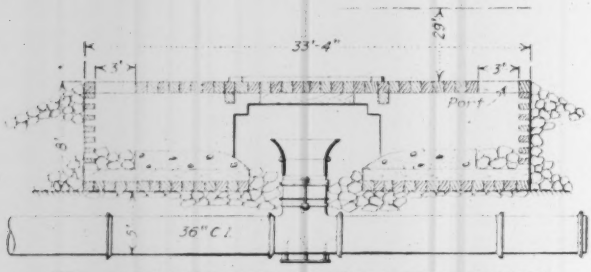


FIG. 4—RACINE CRIB SUPPLIES PIPE INTAKE

of operation upon the continuous presence of a crib keeper to keep the ports free from ice and to maintain the necessary lighthouse equipment.

A typical structure of this type (Fig. 2) located at Chicago is located in 32 ft. of water 2 miles from shore. It is 110 ft. in diameter and is built of heavy stone masonry and concrete. Water is admitted through eight 7x7-ft. ports into a large interior well, from the center of which a vertical shaft extends downward into the tunnel. The heavy masonry shell extends up to the maximum wave influence and is surmounted by a lighthouse. Living quarters are provided for the lighthouse keeper and the extra help periodically required to fight anchor ice. Facilities for the generation of steam to be used when anchor ice is prevalent are also included.

On account of the relatively large quantity of water drawn—up to a total of 1,000 m.g.d. through five similar intake cribs—the velocity through the ports is comparatively high, at times as much as 1½ ft. per second. A continuous supply at such port velocities would be possible only with the services of an attendant and periodical extra help.

Submerged Cribs — The maintenance of a surface crib would be a burdensome expense for a small city. This problem has been solved by the use of a submerged crib. For continuity of supply, without attendants, comparatively low port velocities are sufficient. The depth over such submerged intakes required for navigation varies somewhat with the location of the crib and the depths available in the lake in its general vicinity. The criterion in this regard which influences the Corps of Engineers, U. S. Army, is the information given to lake pilots by the navigation charts as to places usable or to be avoided by lake shipping.

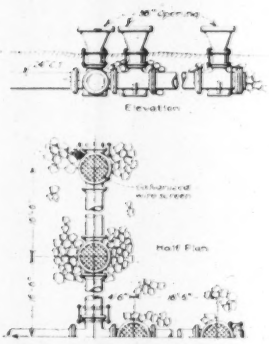


FIG. 5—MULTIPLE INTAKES OF UPTURNED TEES AT GLENCOE, ILL.

The submerged intake crib at Gary, Ind. (Fig. 3), is believed to be a satisfactory solution for a submerged intake crib for a city of 300,000 people. Gary has a present population of about 100,000. This crib has been in use under a gradual increase in pumpage for twenty years with no stoppage from anchor ice. It is located in 44 ft. of water and projects 11.5 ft. above the lake bottom. The crib proper is a 60-ft. octagon closed on top and admits the water through twelve ports in the top cover, each 5x5½ ft. Water passes to the center of the octagon and downward through a 10-ft. shaft to a 6-ft. tunnel leading to the pumping station on shore. Screening is done at the pumphouse shaft. The maximum port velocity to date has been only 0.14 ft. per second. During the critical ice period the velocities so far have been much less than this figure.

A similar submerged intake crib at Racine, Wis., (Fig. 4) has been in use about two years. As at Gary, the ports in this structure are in the top or cover of the crib, without screens. They lie in a horizontal plane 8 ft. above the lake bottom and are designed for maximum port velocities of about 0.25 ft. per second. The timber crib structure is 33 ft. 4 in. square with ports at the outer edges. It is surrounded with loose rock for stability. Racine has a population of about 80,000.

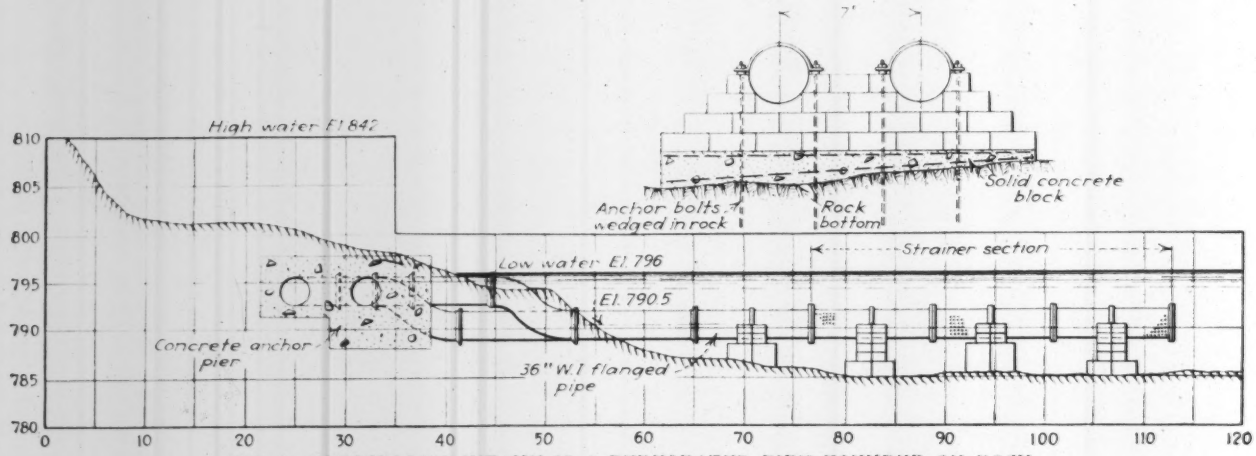


FIG. 6—KNOXVILLE'S INTAKE IS A PERFORATED PIPE FOUNDED ON ROCK

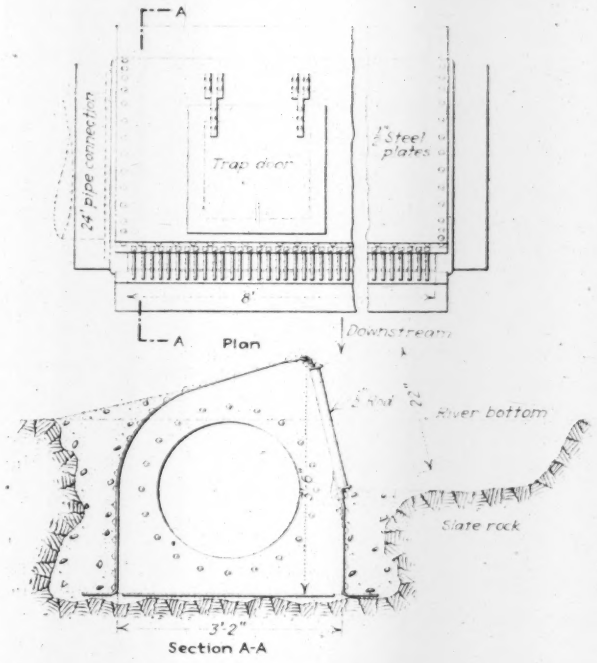


FIG. 7—NEW ALBANY, IND., INTAKE
This type is suitable where it is not desirable that obstructions be placed above streambed. Intake faces downstream so that debris will not enter easily.

Pipe Intake—For smaller towns the desirable features described in the previous lake intakes—namely, moderate port velocities and distribution of draft—can be secured by less expensive construction. The Glencoe intake (Fig. 5) is typical of a supply for about 6,000 people. Large port area and decentralization of intake is secured by dividing the 24-in. cast-iron intake pipe into three branches, thus distributing the intake draft over a 20x65-ft. area. These intake ports are 3,300 ft. from shore, and lie in a plane 4 ft. above the lake bottom, submerged 19 ft. 2 in. at standard low water.

Submerged intakes, generally similar in type to those above described, are widely used throughout the Great Lakes, although the materials employed and the forms and dimensions vary widely. In many cases the intake port velocities are so high as to allow stoppage by anchor ice, but generally such ice is present only a few days or a few hours per year and in some years not at all.

River Intakes With Stable Bottom—The intake structures used upon the Great Lakes would probably not prove satisfactory in flowing streams subject to erosion and silting. In such streams it is desirable to select a location where adequate depth of water is always available and where the bottom is as stable as possible, and to build thereon an intake structure that interferes with the flow of water as little as possible.

Structures similar to the one shown in Fig. 6 (Knoxville, Tenn.) have been used successfully in a number of instances for average rates of pumpage up to 10 m.g.d. A structure of this type is possible only where the river bottom is relatively permanent with sufficient depth of water at low stage to submerge the intake pipe about 3 ft. and sufficient additional depth to allow the current to pass freely under the intake pipe and thus minimize the tendency to create a sandbar. It is not desirable that an intake of this type should project very far from the shore.

The Knoxville intake consists of two 30-in. pipes carried on heavy piers supporting the pipe about 4 ft. above the river bottom. Each pipe is perforated with 1-in. holes on 2-in. centers, and is capped at the end with a perforated plate. The screen thus formed excludes the larger objects. At the location selected for the intake there is a depth of 11 ft. available at extreme low water and a hard and relatively permanent bottom. As it was not deemed feasible to construct such an intake immediately opposite the pumping station because there the river is very shallow with an unstable sand bottom, the two intake pipes run upstream from the pumping station in the shallow water close to the shore, a distance of 700 ft., in order to obtain suitable conditions. The intake pipes end 60 ft. offshore.

Centrifugal low-lift pumps delivering water to a filter plant draw directly from either or both of the suction pipes and intakes. The comparatively long suction pipes are unobjectionable as they are always submerged, except for 235 ft. next to the pumps, where they pass through a tunnel and are thus available for inspection and repairs. A necessary feature for this type of intake is the provision for back-flushing through the inlet to rid the screens of any accumulated material.

The Knoxville intake has been in use three years. A similar intake at Evansville, Ind., has been in continuous use 30 years. At Evansville the bottom is of sand and other lighter, alluvial deposits. The two perforated intake pipes are supported on pile bents. The bottom was too hard to permit the use of piles at Knoxville.

Intakes on Rock Bottoms—Occasionally a situation is found where the water is comparatively shallow with a rapid flow on a rock bottom. If the water is navigable, as is the case at New Albany, Ind., it is not possible to build a structure that extends materially above the general river bottom. The New Albany intake is located near the foot of the Ohio rapids, 100 ft. from shore in water about 3 ft. deep at low water. The 24-in. intake pipe is carried in a trench excavated in the rock. The intake box (Fig. 7) is built of steel plates and faces downstream to encourage the passing of logs and debris. The inlet port is protected by a bar screen. It has an area about five times that of the cross-section of the intake pipe.

Intakes on Soft Bottoms—The intake for the Terre Haute (Ind.) Water Co. (Fig. 8) occupies a location

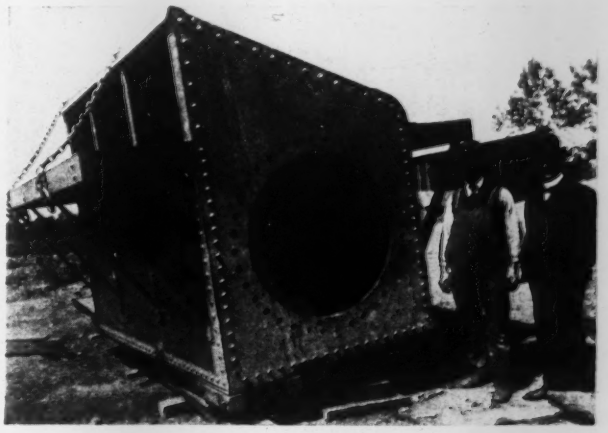


FIG. 8—TERRE HAUTE INLET BOX BEFORE LAUNCHING
This type of intake is suitable for streams with soft bottoms. It is supported on wood piles by means of the brackets shown.

on a bend of the Wabash River that is periodically filling in and cutting out. The filling material is usually a soft river deposit approaching black mud. The intake ports are on the downstream side, permitting debris materials to pass over the intake. The nature of the bottom precludes supporting any material weight, and when the river is cutting upon this bank, supporting materials are entirely carried away. This rather unusual condition is overcome by supporting the intake pipe and box upon piles. The brackets or shelves, shown in the view of the intake box, rest upon the supporting piles.

River Intakes on Eroding Bottoms—Some of the large rivers, particularly in the Southwest, such as the Rio Grande on the Texas border, are subject to flood rises of 40 ft. or more, accompanied by a very rapid current. In such streams the riverbed is constantly changing. During flood the bottom is eroded many feet in depth at some places and replaced at different locations when the flood subsides. In such situations it is difficult to maintain any structure byond the low-water bank of the stream.

The intake built for the water-works of Laredo, Tex. (Fig. 9), illustrates a method frequently employed to overcome these conditions. It is essentially a suction box or well located at the water's edge and of sufficient height to be accessible from the shore under ordinary high-water conditions. Water is admitted through either of two sluice gates in the side of the well. Sliding screens, accessible from the top of the structure, intervene between the sluice gates and the pump suction pipes. This structure is built so that a boom derrick can be accommodated on top of the intake for the purpose of removing sand deposits in front of the ports. Structures similar to these have been built on several other rivers of the South and West where extreme flood heights and unstable riverbottom conditions are encountered. They are

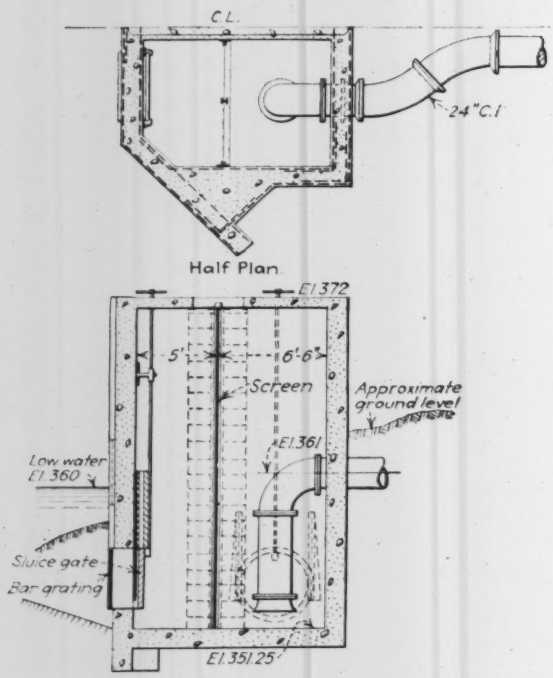


FIG. 9—SUCTION INTAKE AT WATER'S EDGE, LAREDO, TEX.

A structure of this type is often necessary at locations where the streambed is subject to periodic change. The roof of the suction well is above high water.

FIG. 10—CHAIN OF ROCKS INTAKES AT ST. LOUIS, MO.

East intake near bridge. West intake in center. In right foreground, canal and site of new shore intake, now under construction.

likely to give some trouble from sand following erosive river conditions. In some cases, however, they are the best practicable solution for the difficult conditions to be met.

Suction Wells—Until comparatively recent years most water-works pumping has been done by plunger pumps that are easily injured by sand. On the Great Lakes the practice has been nearly universal to terminate the intake pipe at the shore line in a suction well. Usually the intake pipe, several thousand feet in length, is laid upon the bottom of the lake until the shore of the lake is approached. Here it is laid in a trench below the influence of wave erosion. At the water's edge it is usually buried about 10 ft. Thence it enters the suction well horizontally and, by means of an elbow, drops down to the bottom of the suction well to about 30 ft. below lake water level. The suction pipes of the pumps also drop into this well, with screens placed between the inlet pipe and the suction pipe. In this way it is possible to siphon the lake water into the suction well under conditions of heavy pumpage and thus secure 20 or 25 ft. of head to force the water through the intake and intake pipe. In the case of the Chicago water-works, the uptake shafts from the intake tunnels form the suction wells for the pumps. With the increasing use of centrifugal pump machinery, particularly as low-lift pumps for filtration plants, the use of a suction well at the shore line is less necessary, although it is often desirable as a location for screens.

Screens—Wherever possible it is desirable that a screen should intervene between the intake and the pumps to exclude large objects from the distribution system. This is not always necessary when the water is subsequently filtered. River intakes occasionally admit waterlogged pieces of wood that would seriously injure even a centrifugal pump, in which case it is necessary that screens should be used. It is desirable that these screens be located at an accessible place for the purpose of cleaning. Under some conditions almost constant cleaning is necessary for a few days in some years. Electric generating stations, which require large quantities of water for condensing purposes, have found it desirable to install screens which are automatically cleaned. Several types are on the market. Similar screens are used in sewage treatment plants. Generally the amount of water developed must be relatively large to warrant the use of such devices.

Most types of water-works intakes in use today are included in the examples that have been cited, although numerous variations are embodied, influenced by the local conditions and the experience of the designer.

Developments in Water-Purification Practice

Preparation of Acceptable Water Assured by Stable Methods of Design, Improvement of Equipment and Great Adaptability to Meet Multiplicity of Conditions

By Paul Hansen
Of Pearse, Greeley & Hansen, Consulting Engineers, Chicago

Although 1929 was the centenary of slow sand filtration, and its virtual supplanter, rapid filtration, had its crude beginning less than 50 years ago, it is within the last third of a century that the technology of water purification has been placed on a sound basis. Recent progress in water purification, which has many objects and many ways to meet them, is ably summarized in the following article by Mr. Hansen, who leaves to Mr. Hoover's succeeding article a review of water softening. The latter art, practiced abroad for nearly a century, is only now getting a good start here in a number of plants, although the art itself is well advanced, as Mr. Hoover shows. —Editor.

Filtration practice for more than a quarter of a century has shown a surprising degree of stability in design and construction, yet there has been much refinement in practically everything relating to filtration; more convenient plant layouts have been devised, equipment of all sorts has been improved, better understanding and development of coagulation and sedimentation have been brought about, and operating control has greatly improved. Use of rapid sand filtration has been increased almost to the exclusion of slow sand filtration, which is in large part explained by the high turbidities in most surface waters of the United States. Adaptability and ease of control have caused the use of rapid sand filters to be extended to less turbid waters and they are now finding general favor abroad. This article will be confined to rapid sand filtration and changes in filter plant design and filter operation will be discussed in about the order they are encountered as the water passes through purification works.

Preliminary Sedimentation—Settling before applying coagulants has long been recognized as desirable when handling very turbid waters. Preliminary sedimentation is used at Louisville and Cincinnati, the first large cities on the Mississippi River system to use filters. The value and economy of this process has taken on a new aspect with the application of mechanical devices for removing sediment as rapidly as it is deposited. Such an arrangement is especially applicable to the turbid water of the Missouri River and is now in use at Kansas City, Mo., and the Howard Bend Works at St. Louis.

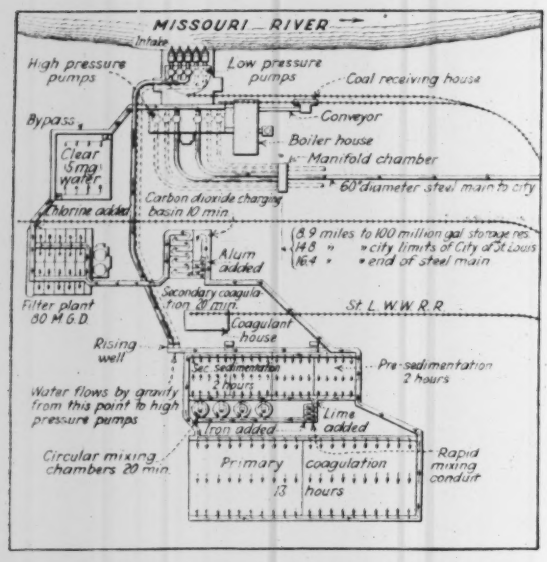
Coagulants—During most of the period dealt with sulphate of alumina (alum) by itself and ferrous sulphate (copperas) in conjunction with lime have been the only coagulants used. Because of the practical difficulty of preventing incrustations of filter sand by water supersaturated with carbonates in the lime and copperas process, alum has found general preference as a coagulant. An impetus was given to the use of alum by the manufacture of crude liquid alum from bauxite at the filter plant by means of arrangements first devised by C. P. Hoover at Columbus. However, lime and iron have been used continuously for many years at Cincinnati and New Orleans. On account of difficulty in obtaining good flocculation of alum with unfavorable temperature or unfavorable hydrogen-ion concentration and because of now available means of recarbonating water before its passage to filters, lime and copperas are finding a new popularity. By adding lime in excess, partial softening can be produced. The heavy ferric hydrate is more effective in dragging down microorganisms than is aluminum hydrate. At some plants, notably Windsor, Ont., lime and copperas are used when algæ are troublesome, and alum is used under normal conditions.

About five years ago sodium aluminate was put on the market as a coagulant. It is effective but expensive. It has the advantage as compared with alum of not increasing the sulphate hardness and not liberating free carbon dioxide. High cost outweighs its advantages. When used with alum it may result in net economy of coagulants.

Within the past eighteen months ferric chloride has been used as a coagulant and has been found very promising both as to effectiveness and economy. It can be most economically and satisfactorily produced by treating a solution of ferrous sulphate with chlorine in solution. An excess of chlorine may be used for sterilization. Ferric chloride and chlorinated copperas were first used for conditioning activated sewage sludge for dewatering by Dr. F. W. Mohlman and Dr. J. K. Palmer, of the Chicago Sanitary District, in 1925. In 1928 it was tried out by Decker and Menke in Alabama and Baylis in Chicago in the coagulation of water and is reported by them superior in economy to any other coagulant.

Chemical Preparation and Feed Devices—Until about ten years ago coagulants were usually dissolved in batches and the solution was stored in large tanks, from which it was fed at a uniform rate by a small feed tank arranged to maintain a constant head over an orifice. Continuous dry measurement of chemicals was first practiced at St. Louis about 1912. Later a number of so-called dry-feed machines were placed on the market and constant improvement has been made in their accuracy, especially for applying small quantities of chemicals. They are much more compact and less messy than solution-feed equipment, with the result that they have been extensively adopted. There is now being tried out at Minneapolis a dry-feed chemical machine which feeds on a continuous-weight rather than a continuous-volume basis. Many automatic batch-weighing devices have long been used, especially for unslaked lime at softening plants.

Great improvements have been made in handling and storing large quantities of chemicals. At the Howard Bend plant, St. Louis, at Minneapolis and at a few other plants, vacuum suction hose are being successfully used.



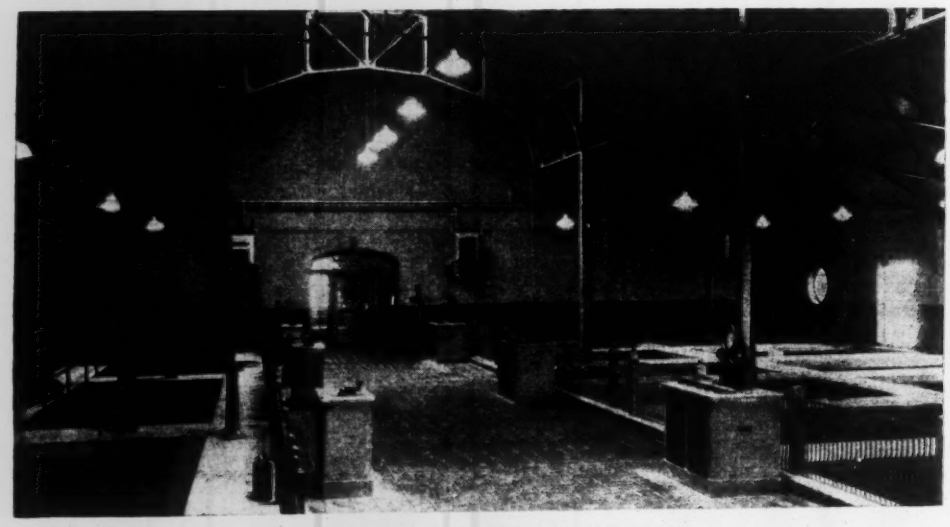
HOWARD BEND FILTERS, ST. LOUIS
An excellent example of modern purification plant practice.

Coagulation—In early filtration practice a solution of coagulant was introduced at any convenient point in the suction of low-lift pumps, inlet pipes to sedimentation basins or in the basins themselves. Importance of thorough mixing of chemicals with coagulants began to be appreciated about 1912. Early plants with large mixing chambers were the Division Ave. filters at Cleveland and the filter plant at Evanston, Ill. At first various forms of baffles were used. In 1920 Charles Gilman Hyde introduced stirring devices at Sacramento and in 1923 Ellms utilized the hydraulic jump. At the Howard Bend plant, mixing is obtained by means of tangential inlets at the periphery of circular mixing chambers. General preference is tending toward stirring devices, because they permit greatest flexibility of control. Practice has tended toward longer and longer periods of mixing as a means of promoting good flocculation. In early practice five to ten minutes was common, while recently at Highland Park, Ill., a mixing period of 50 minutes has been provided to facilitate coagulation in clear or cold Lake Michigan water.

Sedimentation—Very little change has been made in design or operation of sedimentation basins. The trend throughout the period under consideration has been toward longer retention periods. Rarely is the period shorter than two hours; six hours is not uncommon, and periods up to eighteen hours are used to advantage. Continuous removal of sludge has not been used except in connection with softening plants. Under some conditions devices for the continuous removal of sludge from sedimentation basins following coagulation are desirable. They also facilitate introducing artificial turbidity in the raw water by the return of sludge. This is effective in promoting flocculation when the raw water is clear. At Louisville sediment from preliminary sedimentation basins and also from sedimentation basins following coagulation has been returned to raw water when unusually clear with good results. At Winnetka, Ill., artificial turbidity has been effectively and economically imparted by means of ground brick clay applied by a dry-feed machine of the type used for chemicals.

Filters—Prior to the use of rectangular filters of reinforced concrete, rapid sand gravity filters were made up in round wood or steel tubs and were equipped with revolving rakes for stirring the sand during washing. With the adoption of rectangular filters agitation was provided by means of compressed air admitted into the bottom of the filters by means of an independent grid of piping or sometimes with the same grid of piping. A great variety of strainer heads of brass was used in connection with the early piping systems in the bottoms of filters.

Hyde at Harrisburg, Pa., in 1903, designed the first piping system for the bottom of a filter without strainers, using merely perforations in the lateral pipes. He also applied both water and air while washing through the same pipe system. The rate of application of wash water up to this time was about 9 in. vertical rise per minute, roughly three times the rate of filtration. In 1907 Ellms at Cincinnati proposed abandonment of agitation of the sand bed and the use of a vertical rise of water wash of 18 to 24 in. per minute for a shorter period. This high rate of water wash has been in general use ever since and may be regarded as standard practice. There have always been those who felt that water wash alone is not so successful as water wash combined with agitation, particularly agitation with revolving rakes.



FILTER ROOM AT HIGHLAND PARK, ILL.
Mixing chamber at left, filters at right. All operations can be controlled from floor.

Within the past year, Herring and Hulbert in Detroit have established a new conception in connection with the cleansing of filters. They advocate a rate of filter wash which will expand the sand 50 to 60 per cent. This requires a rate of wash of from 36 to 42 in. vertical rise per minute, the rate being somewhat dependent on the variation in

the temperature of the water. Experimentally this has proved very successful and its efficacy has been borne out in practical operation at the Baldwin filter plant at Cleveland, under the direction of W. C. Lawrence. John R. Baylis, of Chicago, fears difficulty with a high rate of wash water and proposes an auxiliary surface wash supplied by a grid of piping placed just above the normal surface of the sand.

Final conclusions as to the best means of washing rapid sand filters cannot now be formulated, but obviously, through the work of Herring and Hulbert, we have obtained a much better understanding of the principles of cleansing filters and in all probability we are on the point of obtaining more efficient methods of washing which will overcome cracking phenomena, mud-ball troubles and many of the unsatisfactory conditions of the filter sand which now harass the filter operator.

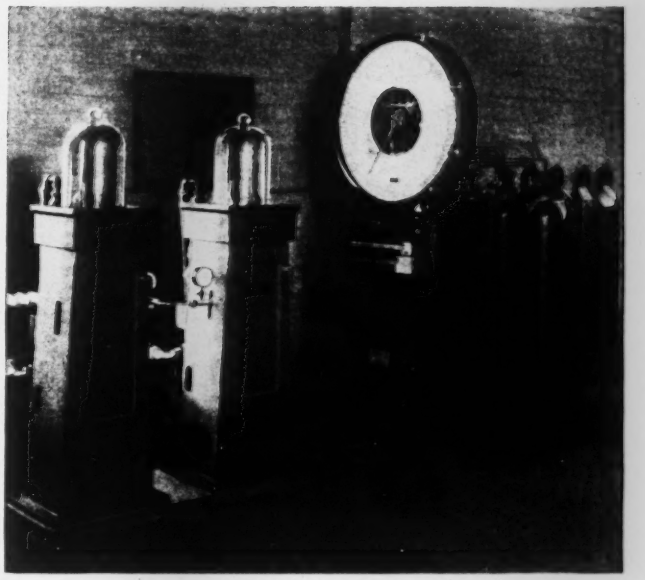
Outside of the change in practice of filter washing, there has been little significant change in the design or operation of the filters proper. There have been some interesting new developments in the design of underdrain systems, the cross-sectional areas of the pipes have been made larger to accommodate more rapid rates of filter washing, and gravel layers under the sand have been made thicker. For a number of years underdrainage systems of molded concrete were favored but now pipe systems are almost universally used. Several filter companies have devised underdrain systems of concrete blocks which permit the use of little or no gravel, and these seem to have some merit. E. F. Delery, of New Orleans has devised a means of perforating copper tubing that so utilizes the velocity head in the lateral pipes as to effect a better distribution of wash water. This arrangement seems to be quite effective, and an economy over ordinary circular perforations is claimed for it.

Shifting of gravel has caused trouble from time to time in rapid sand filters. To overcome this difficulty William Gore, at Windsor, Ont., cemented the top layer of gravel with a small amount of portland cement. Jenks has proposed tile laterals embedded in loosely cemented gravel.

Twenty to twenty-five years ago much stress was laid on using a negative head on the effluent of filters so the filters could be made shallower, thus decreasing cost of construction. Negative head caused more or less trouble from air binding, and the general tendency is now in favor of filter boxes 10 ft. in depth.

Within recent years there has been a tendency to use coarser sand grains than formerly. The increase has been from 0.35 mm. to about 0.55 mm. effective size.

Float and disk rate controls have been practically abandoned in favor of rate controllers of the Venturi type. Rate controllers are also equipped with indicating and recording flow gages. It is now common practice to use recording loss of head gages instead of merely indicating loss of head gages. All of this equipment assists the operator in observing the behavior of the filters to better advantage.



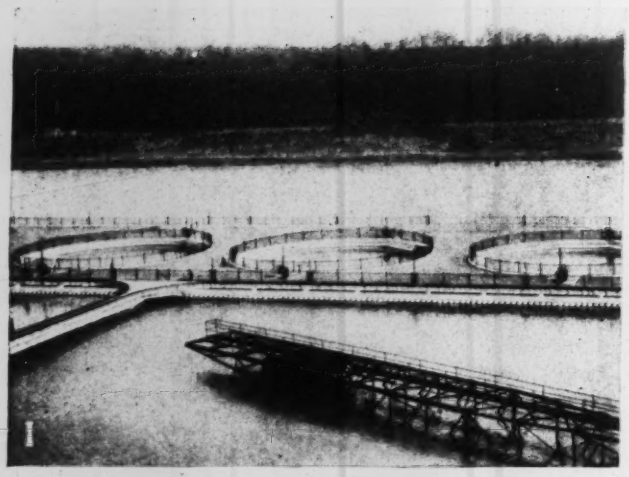
TYPICAL INSTALLATION OF CHLORINATOR EQUIPMENT AT MINNEAPOLIS

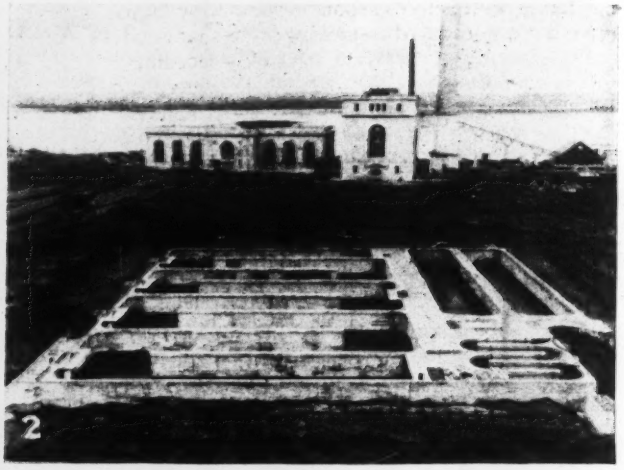
Some clear water storage is necessary in connection with gravity rapid sand filters. It is not used with pressure filters. The latter are practically obsolete in municipal practice and have not been recognized as suitable by well-informed engineers throughout the past 25 years. There has been practically no change in the design of filtered water reservoirs. They are usually placed under and extending beyond the filters and are always covered to prevent the entrance of dirt and sunlight. The modern tendency is to allow more and more clear water storage to avoid excessive filtration rates. Storage is not properly a part of the filtration process, hence this article will not deal further with the question of appropriate storage capacities.

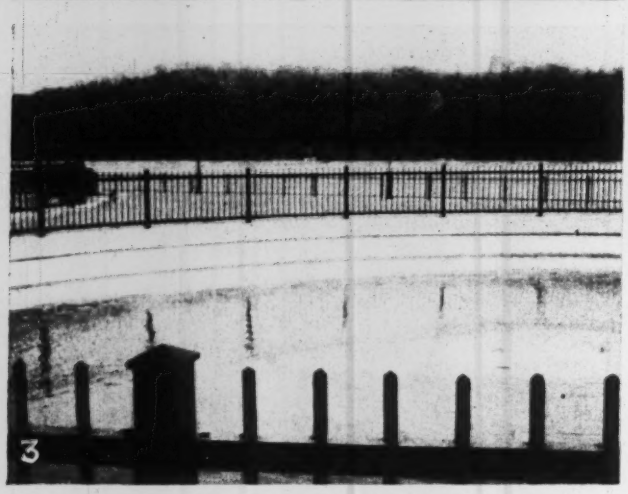
Wash Water Storage—In the great majority of filter plants, especially those of small size, wash water is furnished by special pumps taking the suction from the clear water reservoir and delivering the discharge directly into the filter underdrains system. A preferable arrangement is an elevated tank supplied by small pumps operating more or less continuously. The early practice of taking wash water from the distribution mains is now regarded as undesirable, though in small plants emer-

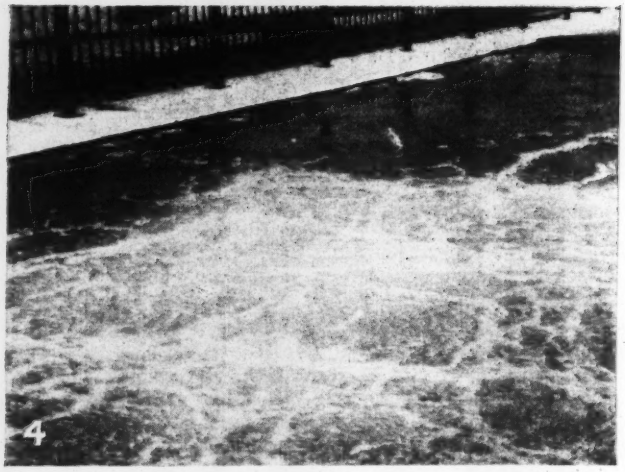
FILTER PLANT AND PUMPING STATION AT KENILWORTH, ILL.

Buildings are located on the shore of Lake Michigan at the end of a main street of a suburban residence community. Plant designed so as not to obstruct view of lake. Roof is paved and used as an observation terrace, and dressing booths and showers for use of bathers are housed in the building.









HOWARD BEND WATER PURIFICATION PLANT, ST. LOUIS, MO.

1. Primary sedimentation. Plain sedimentation in basins in background; spiral-flow mixing tanks in center; sedimentation with continuous sludge removal in foreground.

2. Secondary sedimentation and carbonation. Mixing chamber at lower right; secondary sedimentation at left; carbonation at upper right.

3. Multiple vortex at outlet of mixing chamber. Four vortices form over central square outlet sump, rotating rapidly with direction of flow.

4. Carbon dioxide applied to water prior to filtration; gas diffused through water by grid of perforated distribution pipes at bottom of chamber.

gency connections are often left for this purpose. A good practice is to place a combination rate controller and Venturi meter in the main wash water line, so that the rate of flow may be effectively controlled and the actual amount of wash water used recorded.

Chlorine—Mention has already been made of the use of chlorine in connection with rapid sand filter practice. Elaboration in the use of chlorine since its first adoption is a noteworthy development. Originally it was used solely as a sterilizing agent for filtered water. More recently it has been found effective for pretreatment in color removal, in combating organism troubles and in assisting effective coagulation. Where phenols are present in water as a result of pollution by industrial wastes, the chlorine applied at a low rate has produced disagreeable tastes and odors due to the formation of chloro-phenols. A large excess of chlorine has been found to eliminate phenol tastes, but the chlorine taste still remains. To overcome this taste the water must be dechlorinated. Howard, of Toronto, has effectively used sulphur dioxide for dechlorination. Sodium thiosulphate and potassium permanganate may also be used for dechlorination, but are more expensive. The use of potassium permanganate alone applied to the raw water has been found effective in eliminating phenol tastes. It was first used at Rochester, N. Y., by Caird and is now in regular use at East Chicago, Ind.

The application of ammonia prior to chlorination, resulting in the formation of chloramines, has been found effective, especially at Ottawa, Canada, in avoiding the characteristic chlorine taste. More recently it has been used at Greenville, Tenn., and at Springfield, Ill. There is evidence that chloramines are more effective as sterilizing agents than chlorine itself.

Removal of Tastes and Odors—The use of superchlorination followed by dechlorination as a means of overcoming tastes and odors has already been mentioned. A common method of combating tastes and odors due to microscopic organisms has been aeration. Aeration has not been a complete solution of this problem, however. It is useless in connection with industrial wastes such as phenols. Perhaps the most effective use of aeration is as a means of ridding the water of carbon dioxide in solution which in some waters proves troublesome. It also has proved effective in securing a good mixture of coagulant with the raw water and is essential for iron removal.

Within the past few years there has been much experi-

mentation with active carbon, especially by Baylis in Chicago, as a means of removing tastes and odors from water. According to Baylis and also according to Imhoff in discussing German experience with active carbon, this substance is remarkably effective in removing both phenol and chlorine tastes from water. Its economy is apparently good. To use active carbon will require the most marked modification in the design of mechanical filter plants in 25 years.

Correction of Corrosive Qualities—Many surface waters, especially soft waters, have corrosive qualities. Lime has been effectively used as a corrective. It not only has a direct chemical effect but it also results in a slight coating of the pipes which acts as a direct protection. Correction of corrosion must be carried out with skill and care to avoid excessive incrustation of pipes. When used in conjunction with filtration, the lime should be applied to the filtered water and not to the raw water.

Laboratory Control—There has been no notable advancement in providing laboratory facilities at filter plants. The Little Falls filter plant was well provided with laboratory facilities and practically every major installation since then has had ample laboratory space. Laboratory control, however, has unquestionably advanced. Perhaps the most important single addition is the determination of hydrogen-ion concentration.

One of the notable factors in rapid sand filter practice has been the tendency during the past 25 years to place filter plants in charge of technically trained operators. To these men, more than to any other group, is due the credit for nearly all of the refinements in and increased efficiency of filtration practice in recent years.

Architectural Treatment—An article of this character would not be complete without some mention of improved architecture of the buildings which house rapid sand filter plants. In early practice any sort of building, however cheap and plain, was deemed satisfactory. Little by little the architecture has improved until today many of our larger filtration works are provided with beautiful and dignified superstructures.

Future Developments—It is difficult to forecast future developments. Some have been indicated in what has already been said. Safe public water supplies are now almost universal. Hence, future development in water-purification practice is certain to be concerned primarily with improving the physical and chemical characteristics of the water by the effective removal of color, tastes, odors and those mineral constituents which cause hardness. No doubt there will be added improvements in equipment for controlling processes, in arrangement of plants and in economics, but these are not likely to be revolutionary in character.

Progress and Trends in Water Softening

Greater Degree of Softening Now Obtained—Excess-Lime Method Followed by Carbonation—Combination of Zeolite and Lime-Soda Softening

By Charles P. Hoover

Chemist in Charge, Water-Softening and Purification Plant, Columbus, Ohio

Both chemical and mechanical features of water-softening installations have experienced rapid development in recent years. Those processes which depend upon chemical precipitation for their action have been characterized by a more scientifically accurate control of the chemicals added to the water, and by the refinement of the processes through subsequent carbonation. Base-exchange methods of softening have proved to be suitable for use in conjunction with the lime-soda processes, thereby effecting ultimate economies in many cases. Combinations of softening and iron-removal processes have been found to be especially valuable in the case of well supplies.

In 1929 approximately 110 cities and villages in the United States distributed a softened or partly softened water, with 98 plants using the lime or lime and soda-ash process and twelve the zeolite process. More than 50 per cent of these softening plants are located in three states, Ohio having 29, Pennsylvania 20 and Florida 11.

All the states in the Union have hard water except (1) those on or near the Atlantic coast, not including Florida, and (2) Oregon and Washington. The generally recognized extremely hard-water states are Ohio, Indiana, Illinois, Iowa, South Dakota, Nebraska, Kansas, Arizona, Florida and part of Pennsylvania. Many hard-water supplies are in small communities which usually take water from wells.

Chemistry of Water Softening Understood—The chemistry of water softening is now well understood and an exact prediction of the results to be obtained can be made. Hardness in water is due to calcium and magnesium compounds in solution. If they are present as bicarbonates, they can be precipitated by lime. If they are present as sulphates, chlorides, or nitrates, they can be precipitated by soda ash. Hard water may be softened by zeolite, because zeolite has the property of replacing the calcium and magnesium in the water with sodium.

Until very recently an average reduction of carbonate hardness to 50 or 60 parts per million (p.p.m.) was considered as good as could be obtained. Many softened waters having as much as 85 or 95 p.p.m. of hardness have been recorded. The results obtained depended largely on the character and temperature of the water treated. High magnesium content and low temperatures were the two factors that were the most difficult to overcome by softening processes in general use until recently. It is now possible to reduce carbonate hardness of all types of water and under all temperature conditions to approximate the theoretical limit—that is, to less than 20 p.p.m.

Theoretical Limit—A theoretical limit of softening may be accomplished by either one of two methods: (1) excess lime treatment followed by carbonation, or

(II) excess lime, carbonation and return sludge. The procedures are as follows:

I. (*a*) Add from 25 to 50 p.p.m. of lime in excess of that theoretically required to combine with the free and half-bound carbon dioxide and to precipitate the magnesium.

(*b*) Remove settleable precipitates by sedimentation.

(*c*) Recarbonate with carbon dioxide gas to the point where the total alkalinity minus two times the phenolphthalein alkalinity equals approximately 5.

(*d*) Filter through sand filters.

II. (*a*) Use from 25 to 50 p.p.m. of lime in excess of that theoretically required to combine with the free and half-bound carbon dioxide and to precipitate the magnesium.

(*b*) Remove settleable precipitates by sedimentation (this is preferable but not essential).

(*c*) Neutralize excess lime with carbon-dioxide gas, the equation being $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$.

(*d*) Mix with large excess of calcium carbonate sludge produced from water-softening reactions or any other inert finely divided material.

(*e*) Settle.

(*f*) Filter.

Scale Formation Prevented by Carbonation—Difficulties encountered in the early days of lime or lime-soda water softening in distribution systems, meters and hot-water pipes on account of scale formation have been eliminated by stabilizing the softened water with carbon dioxide. This result is accomplished by burning coke, pulverized coal, oil or gas in a suitable furnace (Fig. 1) and forcing the gas, after being passed through a scrubber and drier, into the water. The gas is diffused through the water by a suitable distributing system.

Maintaining Chemical Balance—Simple tests for determining equilibrium or chemical balance have been devised. It is possible to determine easily whether water delivered to consumers is saturated, supersaturated or undersaturated with calcium carbonate. This is done by adding calcium carbonate to the water in excess. If the water is undersaturated, the alkalinity will increase; if saturated, it will remain constant; if supersaturated, it will decrease. Water that is supersaturated with calcium carbonate will deposit a coating on the insides of pipes, and if continued too long the pipes will become clogged. On the other hand undersaturated water may cause corrosion.

Handling and Application of Chemicals—Methods of handling, storing and applying chemicals have been improved. Large quantities of chemicals can now be handled economically by unloading them from cars by means of pneumatic conveying devices (Fig. 2.) The measurement and feed of chemicals from dry-feeding machines may be controlled by both measurement and weight so that the application of the chemicals to the water will be uniform no matter whether the chemical is coarse, fine or a mixture of coarse and fine.

Zeolite—Zeolite is sodium aluminum silicate but becomes calcium magnesium aluminum silicate after hard water is passed through it. It may then be regenerated or reverted to sodium aluminum silicate by backwashing it with a solution of common salt (NaCl). The hardness of water when passed through active zeolite softeners at proper rates is reduced to practically zero.

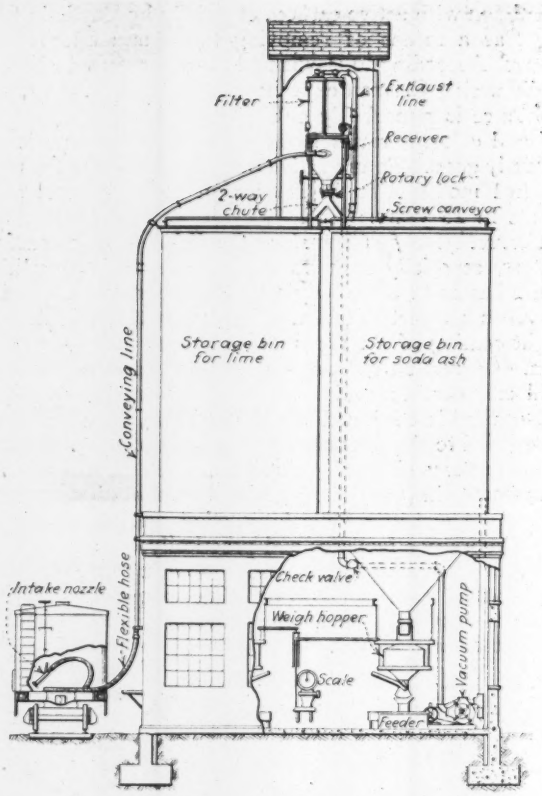


FIG. 2—PNEUMATIC CONVEYING EQUIPMENT FOR HANDLING CHEMICALS

Zeolites first used, although of comparatively high capacity, were low in rate of activity. They were slow in softening and long periods of time were required for regeneration. They were also inefficient in salt consumption, using from two to three times the amount of salt required for the regeneration of modern rapid zeolites. The modern zeolites are greensand, found in extensive deposits in New Jersey and elsewhere, and the more recent gel types. Greensand must be thoroughly washed and screened to proper size before it is ready for use as a water softener; in addition, it is usually processed. The gel type zeolites are of synthetic origin and are made

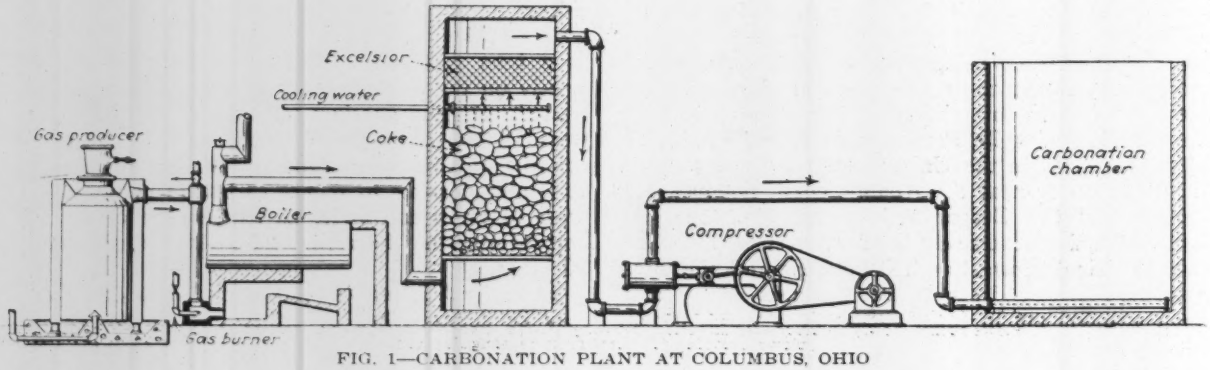


FIG. 1—CARBONATION PLANT AT COLUMBUS, OHIO

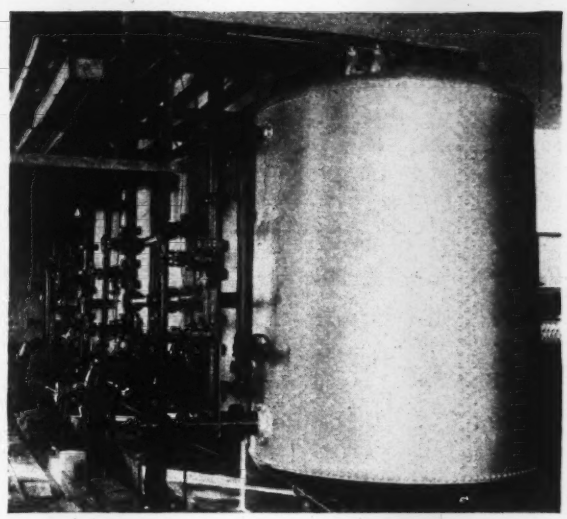


FIG. 3—IRON-REMOVAL WATER SOFTENERS AT NEW BREMEN, OHIO
Each unit will treat 13,533 gal. of water between regenerations when hardness is 27 grains per gallon. Regeneration requires 203 lb. of salt per unit.

by precipitation processes. They are much more porous than natural zeolites and, pound for pound, have from two to three times the capacity of the greensand.

Where salt can be obtained at low cost, it is cheaper to remove non-carbonate hardness (sulphates, chlorides or nitrates) with zeolite than with soda ash. Whether or not the cost of salt exceeds the cost of lime and soda ash depends on the relative amounts of carbonate and non-carbonate hardness to be removed. The higher the non-carbonate hardness the more economical zeolite becomes as a softening agent.

Advantages claimed for the zeolite process are: (1) Only one chemical is needed (common salt); (2) Variations in hardness of raw water are automatically taken care of; (3) There is no sludge.

Disadvantages are: (1) The water must be clear; (2) The softened water contains residual sodium bicarbonate if carbonate hardness is removed.

Lime-Zeolite Process—Recent advances in water softening have made it possible to use a combination of the lime and zeolite processes in softening certain types of hard water. In operating a lime-zeolite softening plant, the bicarbonate hardness is precipitated by lime. After settling, carbonating and filtering, the water flows through zeolite softeners to remove the sulphates, chlorides and nitrates. If the hardness is to be reduced to zero, all the water is passed through zeolite softeners. If it is desirable to leave some residual hardness in the water, then only a portion of it is so treated.

Softening and Iron Removal by Zeolites—It has recently been demonstrated, at least in one plant in Ohio (Fig. 3) that downflow greensand zeolite softening will remove both ferric and ferrous iron from water. The zeolite removes iron even after its capacity for removing hardness has become exhausted. As a result of this reaction, an especially promising field for zeolite softening will in the future exist in villages or small municipalities because, by the use of this process, water may be pumped directly from the wells through the softener to the distribution system, thus eliminating double pumping, aeration and sand filtration. Iron-free water of any degree of hardness may be obtained. The runs through the softener units may be staggered so that one unit is removing iron while another is softening. That is, a unit will be kept in service after it has become exhausted or incapable of removing hardness, functioning as an iron-removal filter. The hard iron-free water may then be mixed with zero-hardness water in any proportion so as to produce the desired degree of hardness.

Sludge Disposal—In some cases the disposition of sludge produced by lime and soda-ash softening has not been satisfactory. Almost all modern plants are now equipped with clarifiers that remove the sludge continuously and this has simplified the problem. Fortunately, many plants are located near large streams of water and the continuous discharge of sludge into the stream is not objectionable. Where a stream is not available for sludge disposal, the sludge may be dewatered by means of a filter of the suction type, or it may be lagooned. If dewatered by filtration, lagooning or kiln-drying, it has value as a substitute for ground limestone or lime for soil treatment. Burning it into lime has also been considered.

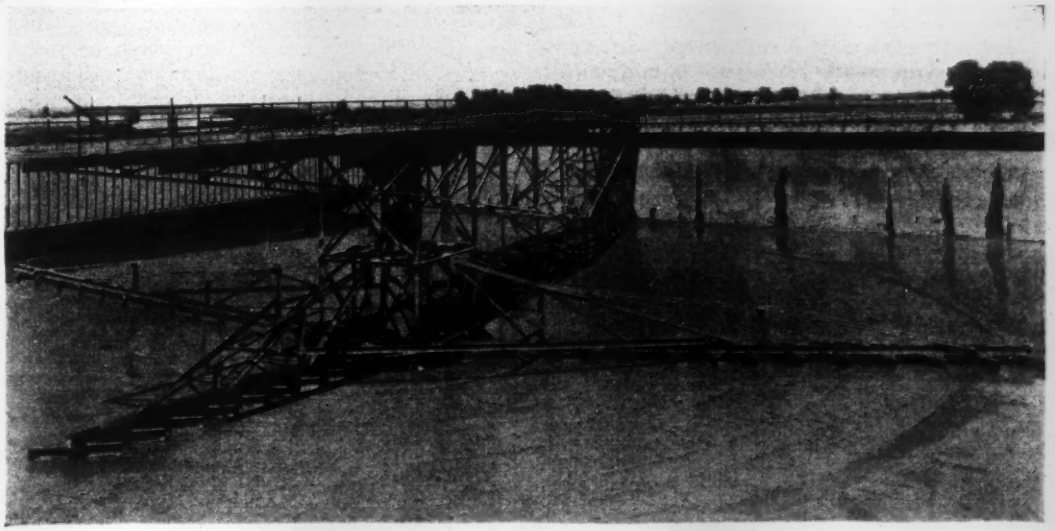


FIG. 4—CONTINUOUS SLUDGE REMOVAL EQUIPMENT AT ST. LOUIS, MO.
Plows rotate slowly in clockwise direction, drawing sludge toward central sump. Auxiliary set of plows provides for corners of rectangular basin.

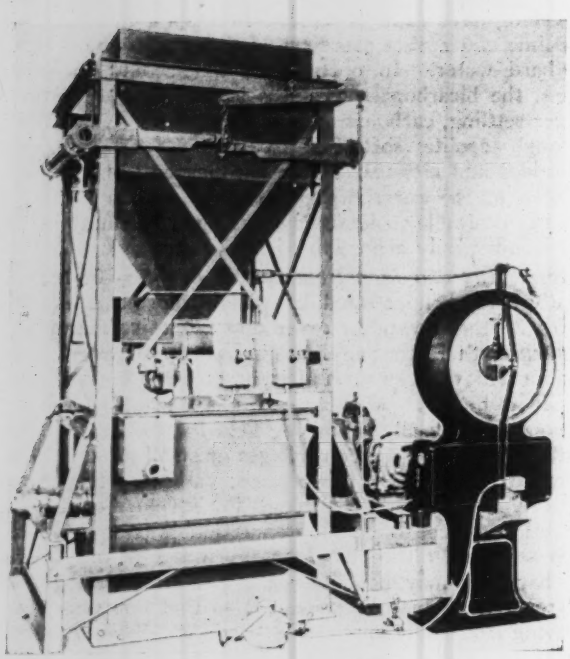


FIG. 5—LIME FEEDER AND SLAKER AT MARION, IND. Feed is controlled by weight and is proportioned to amount of water pumped.

Combined Softening and Storage—The installation of a lime-soda softening plant in a small municipality using well water can be designed as a combined water-softening and storage plant, thus affording available water storage above ground. This is a valuable adjunct in case of operative emergencies or large fires, and will be taken advantage of by many small communities.

Combined Iron Removal and Softening—The officials of many communities where hard iron-bearing well water is used as a source of supply favor the removal of the iron, but want to omit softening, as they fear that softening will affect the potability of the water. It has been demonstrated repeatedly that softened well water is excellent tasting water; nevertheless the prejudice exists. If a plant is built for removing iron from hard water, it should be built so that it can be converted readily into a combined iron-removal and softening plant, because the trend is for soft water as well as for iron-free water.

Trends—During the past five years municipalities having raw water supplies with hardness in excess of 150 p.p.m. that have had occasion to build plants to improve their water supply have in almost all cases made provision for softening or have so arranged the plants that softening equipment can be added easily. This practice will no doubt continue.

Lime is the cheapest chemical available for removing carbonate hardness from water. It not only reduces the hardness but is exceptionally well adapted to the treatment of a badly polluted hard water, because coagulation is improved; organic matter, color, objectionable gases and iron are removed, and bacteria are killed. If a sufficiently high causticity is maintained, it is unnecessary to depend on chlorine if tastes and odors are feared, thereby making it possible at times to produce a satisfactory potable water from a badly polluted water high in organic matter. It is a real adjunct to water purification, because it increases the efficiency of sedimentation and filtration processes. It will probably continue to be used by large municipalities to remove bicarbonate hardness and most certainly by municipalities softening surface supplies.

Combination of the lime and zeolite processes will probably be adopted by larger municipalities having to soften water containing both carbonate and non-carbonate hardness. It is believed that the zeolite used along with the lime is justified when there is 85 p.p.m. or more of non-carbonate hardness to be removed.

Water Softening Association Recommended for Education of Public

By A. M. Buswell
Chief, Illinois State Water Survey, Urbana, Ill.

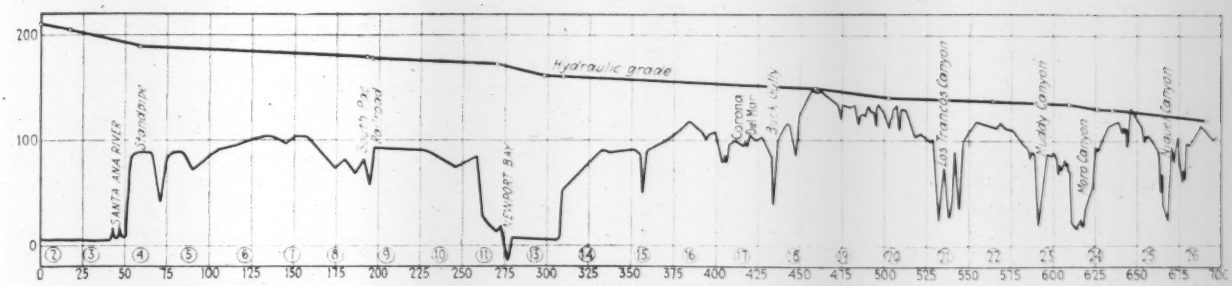
Although satisfactory methods of water softening have been known for nearly a hundred years, the general public appears to be almost entirely ignorant of that fact. As evidence of this, attention is called to the relative infrequency with which hard water is treated either for municipal or for industrial use. For example, in Illinois every public supply should be treated for the removal of hardness, and yet only 1 per cent of our municipalities have water-softening plants.

While water softening for industrial purposes is somewhat more common than for municipal uses, there is a surprising number of manufacturers who fail to avail themselves of its benefits. The writer has taken occasion to ask various persons who are engaged in the manufacture of water-softening apparatus and equipment what, in their estimation, were the opportunities for development in this field. Or to put the question in another way, of the water supplies in this country which, from an economic standpoint, should be softened, what percentage is softened? The answer to the question has been, "Not over 10 per cent." In other words, the market for water softeners is only one-tenth saturated.

In view of these facts, the writer feels very strongly that if the manufacturers of water-softening equipment in this country could unite to form an association whose purpose would be the education of the public in the benefits of water softening, there would soon be a greater demand for the necessary equipment than all the manufacturers together could supply. When one considers the tremendous economic waste which results annually from the use of hard water, he feels impelled to urge that every possible means be employed to bring about the elimination of this waste.

TILE METER BOXES USED AT KANSAS CITY

Cover being held up by John J. Geary, Superintendent Meter Division



Profile of Laguna Beach Pipe Line

Constructing a Pipe Line in Corrosive Soil

Pipe Making and Laying Methods and Costs on a 12-Mile Line of Cement-Coated Welded Steel and Spun Concrete Pipe for Laguna Beach, Calif.

By J. B. Lippincott and K. Q. Volk
Lippincott Engineering Offices, Los Angeles, Calif.

Broad Reviews of design practice, with numerous specific examples, in preceding articles, are here followed by details of both design and construction, with itemized costs applied to a single project. The main problem is one common to all water-works—a pipe line to connect source of supply with a distribution system. Not so common is choice of pipe to resist exterior attack from corrosion attack. The soil-resisting power of portland cement was the main reliance in each case, but with this notable difference: for the portion of the pipe line under low pressure, centrifugally spun concrete pipe was used, reinforced with steel, whereas for the high-pressure portion, electrically welded steel pipe was chosen, with a reinforced cement coating applied with a cement gun.
—Editor.

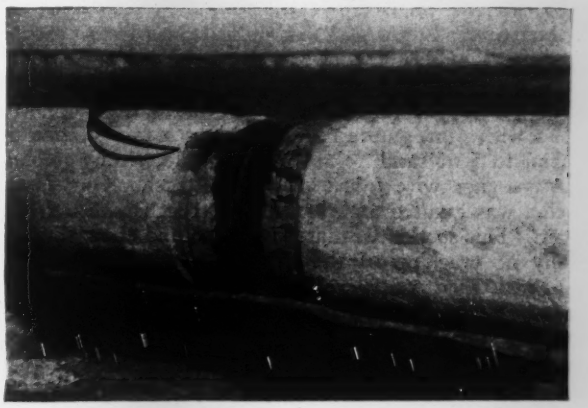
In our Western states it is necessary for small cities, in the early period of their development, to keep down their water-works construction costs and at the same time get a water system which is adequate to meet their needs for years to come. Often the need for low unit costs is increased by the necessity of constructing a long pipe line or aqueduct to reach a reliable source of supply. Soil conditions may also enter into the choice of pipe material. The Laguna Beach County Water District is a case in point. To meet economic and soil conditions there, a 11.6-mile supply conduit, partly of gunite-coated electrically welded steel pipe and partly of centrifugally spun reinforced-concrete pipe has been built, in diameters of from 30 to 18 in.

Laguna Beach, which is one of the oldest beach cities in California, is located about 35 miles south of Los Angeles. The winter population in 1927 was 1,500; the summer population exceeds 6,000. Water was formerly supplied to this community by a private company from wells located in small canyons back of the town. On account of the recent dry years in southern California, this supply practically failed and it was therefore necessary to seek a new source. The Laguna Beach County Water District, 1,450 acres, was formed, and joined with the Irvine Ranch Co., owner of a large tract of coastal land between Laguna Beach and Corona Del Mar. It was found that a reliable supply could be obtained from wells located in the delta of the Santa Ana River, 11.6 miles north of Laguna.

Studies were made of various locations for the pipe line and of practically all classes of pipe then in use in California. The total cost of the line over a period of years was estimated for various sizes and kinds of pipe, the estimates including interest, depreciation, maintenance, operation and pumping expenses. Consideration was given to the coefficient of friction for various classes of pipe and their estimated length of life.

The pipe line has a maximum capacity of 15 sec.-ft. for 75 per cent of its length, reducing to 5 sec.-ft. at the end of the line. Of the total length of 11.6 miles, over 8 miles is a 30-in. steel force main and the remainder 27- to 18-in. concrete gravity main. The maximum head on the force main, including water hammer, is about 250 ft., and the maximum head on the gravity line 125 ft. Practically throughout its entire length the pipe line passes through sedimentary soils of a marine character which have a high corrosive action on steel pipe.

Estimates showed that the cost of building this line of cast iron was beyond the financial resources of the district. Prior to this time the two types of pipe which have been generally used in California for this class of



ARC-WELDED JOINT IN CEMENT-COATED STEEL PIPE

TESTING CEMENT-COATED STEEL PIPE TO DETERMINE VARIOUS DESIGN FACTORS

construction work were reinforced concrete and riveted steel.

In studying the feasibility of protecting steel pipe with gunite it was found that the late James D. Schuyler, an eminent California engineer, gave that method a trial some fifteen years ago. He installed 200 ft. of 12-in. fourteen-gage steel pipe in the system of the Sweetwater Co. in San Diego County. Chicken wire was used for reinforcement and ½-in. gunite applied over an asphalt dip. Field examination by E. A. Rowe, in 1926, showed the steel to be bright and the gunite in good condition.

Our economic study indicated that for the pressure or force-main part of the pipe line, steel pipe, with electrically welded girth and longitudinal seams, coated on the outside with gunite to protect the pipe from corrosion, would make the most satisfactory installation at a reasonable cost; while for the gravity portion of the conduit, centrifugally spun reinforced-concrete pipe was selected. Considerable experimental work was done on sections of electrically welded 30-in. steel pipe of varying lengths. After being thoroughly coated with gunite these sections were tested for external load to determine the deflection the pipe would stand without cracking the gunite as well as its durability under ordinary conditions of handling, together with the proper thickness of steel and gunite coating, and the most satisfactory type of reinforcing and gunite mix. The testing of short sections, while interesting and of value in determining the proper thickness of steel and gunite, was not conclusive as to the experimental load the pipe would stand, owing to the relatively short sections tested and the method of loading. The test indicated that, to prevent cracking, the thickness of plate was of greater importance than the thickness of gunite coating. For the 30-in. portion of the line it was decided to use $\frac{3}{16}$-in. plates with ¾-in. gunite coating having a mix of one of cement to 5 of sand, reinforced with electrically welded fourteen-gage wire fabric of 2x4-in. mesh. One 24-ft. section was gunited and buried in a trench with 6 ft. of cover. This section was later removed and showed practically no cracking of the exterior coating. This section was then given rather severe handling without damage to the gunite. These experiments demonstrated the importance of proper curing and the necessity of bracing the pipe in the interior to bring it to a true circle until the gunite had cured, after which the braces could be removed without damage to the protective coating. Data were obtained from these experiments upon which to base an estimate of cost for doing the work.

Experiments were also conducted on centrifugally spun concrete pipe to determine the proper mix, type of reinforcement, time and rate of spinning. The experimental sections were tested under external pressure with satisfactory results. Hydrostatic tests were made for seepage.

The 30-in. pipe forming the force main was manufactured from $\frac{3}{16}$-in. plates 16 ft. long. Each section was made up of two plates, the longitudinal seam being automatically electrically butt-welded. Two 16-ft. sections were joined by an automatic electrical lap weld and the pipe was made of inside and outside courses, the minimum internal diameter being 30 in. These 32-ft. lengths were tested to 150 lb. pressure. After testing, the pipe was preheated and vertically dipped in an asphaltic solution. After unloading the pipe from the cars at the contractor's yard near the work, interior bracing was placed in each pipe to bring to a true circle. Three sets of braces were used in each section, one at each end and

TABLE I—COST DATA, LAGUNA BEACH PIPE LINE

43,451 linear feet of 3-inch $\frac{3}{16}$-inch gunited steel pipe*

	Contract Price	Total Cost	Length, Ft.	Cost per Foot For Quantity Done	Cost per Foot For Entire Job
Trenching and backfill (H. W. Rohl, general contractor):					
General expense		$3,349.00	43,451		$0.077
Machine trench		11,005.26	39,261		
Hand trench		1,976.25	1,879		
River trench		4,544.68	1,255		
Total trenching		$17,526.19	43,451		$0.242
Excavation and piers for pipe laid above ground		774.00	770	1.005	0.018
Sand for backfill		4,160.56	34,900		0.096
Bellholes		6,193.49	41,140	0.151	0.142
Backfill		5,454.01	41,140	0.132	0.126
Total trench and backfill	$1.695		43,451		$0.701
Steel pipe, including freight to yard and field welding and painting (Steel Pipe & Tank Co., subcontractor)	$3.075		†43,451		†$3.075
Guniting steel pipe, including trucking from yard to trench and lowering in trench (Cement Gun Construction Co., subcontractor):					
Yard work:					
Plant		2,379.74	43,451		0.055
Moving pipe in yard		243.32	43,451		0.006
Bracing interior		291.96	43,451		0.007
Reinforcing, labor and material		8,351.55	43,451		0.192
Guniting, labor, material and equipment		19,573.31	43,451		0.450
Curing		923.92	43,451		0.021
Total yard work		$31,763.80			$0.731
Field work:					
Loading		1,247.68	43,451		$0.029
Hauling		3,578.96	43,451		0.082
Laying		3,348.07	43,451		0.077
Field joints		4,352.55	43,451		0.100
Total field work		$12,527.26			$0.288
Total guniting	$1.500		43,451		1.041
Total exclusive structures and special fittings	$6.27				$4.817

*The figures represent field costs only. They do not contain contractor's profit, costs of bonds or any expenses of contractor's home office. All costs of structures were paid separately and are not included in the above costs.

†Sub-contract price.

TABLE II—COST DATA, LAGUNA BEACH PIPE LINE

17,644 Feet Centrigufal Concrete Pipe

Item	27 In. 10,574 Ft. Total Cost	27 In. 10,574 Ft. Cost Per Foot	24 In. 5,520 Ft. Total Cost	24 In. 5,520 Ft. Cost Per Foot	18 In. 1,570 Ft. Total Cost	18 In. 1,570 Ft. Cost Per Foot
Total costs, exclusive of cost of pipe in yard (Western Concrete Pipe Co., subcontractor):						
Cartage and unloading	$5,704.00	$0.539	$1,930.50	$0.350	$385.79	$0.245
Machine trench	2,992.00		1,510.54		360.00	
Hand trench	845.50		1,506.10		101.50	
Total trenching	$3,837.50	$0.363	$3,016.64	$0.546	$461.50	$0.294
Bellholes and trimming	3,603.90	0.341	1,731.20	0.323	222.56	0.141
Sand for trench	2,556.33	0.242	1,536.40	0.278	414.00	0.262
Pipe laying	7,683.06	0.727	3,806.24	0.690	424.20	0.27
Caulking	1,496.69	0.141	781.58	0.141	100.75	0.064
Supervision	1,935.90	0.183	865.56	0.157	201.66	0.128
Backfilling, repairing defective joints, cleaning up and all expenses after all pipe laid prorated	*7,281.75	0.689	*3,231.60	0.586	657.51	0.419
Total cost exclusive of pipe	$34,099.13	$3.225	$16,949.72	$3.071	$2,872.97	$1.827

Total average contract price including pipe, laying and trenching:

Head, Ft.	Price	Length, Ft.	Price	Length, Ft.	Price	Length, Ft.
25	$5.01	4579	$3.85	325	$3.25	1213
50	4.65	4196	4.05	2582	3.40	357
75	4.60	595	4.35	2050		
100	5.80	522	5.25	266		
125	6.10	682	6.00	297		

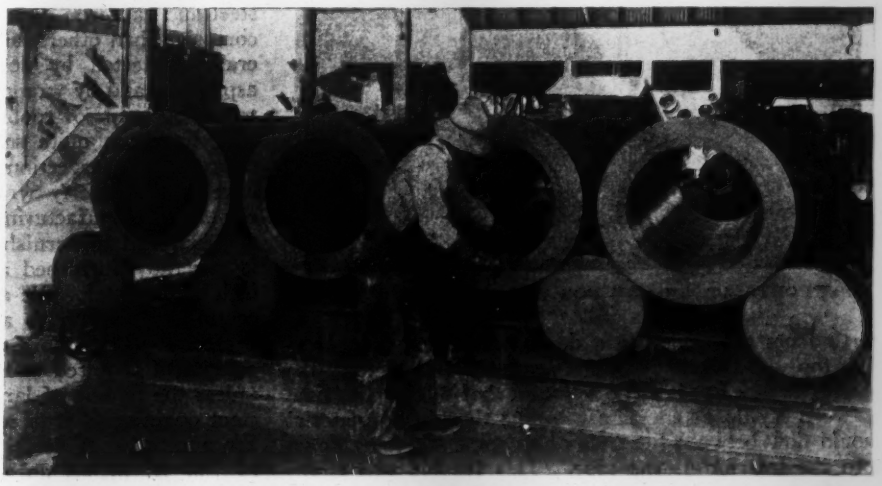
Note: The above costs represent field costs only. They do not contain contractor's profit, cost of bond or any expenses of contractor's home office. All costs of structures were paid separately and are not included in above costs. *Includes prorated costs after Feb. 16, 1926.

one in the center. The steel pipe was next covered with a 14-in. galvanized electrically welded fabric with the roundabout wires on 2-in. centers and the longitudinal wires on 4-in. centers. This fabric was crimped so that when it was laid against the pipe it was held uniformly ½ in. from the outside of the pipe. For convenience in handling, the 32-ft. sections were rolled along wooden tracks supporting the ends. The pipe was next given a ¾-in. coating of gunite, a 1:5 mix being used. As the gunite was applied the pipe was rolled forward. The gunite was carried up to within 12 in. of the ends of the pipe. After two hours the pipe was covered with burlap and kept continuously wet during the daylight hours as long as the pipe was in the yard. No pipe was allowed to be removed until it had cured at least ten days. Care was taken to see that all pipe was laid within 48 hours of its removal from the yard. All special angles were covered with gunite in the yard. On account of the length of sections it was necessary to haul the pipe to the side of the trench with truck and dolly. To prevent the gunite coating from being damaged, rubber cushions were used. Three sections were hauled to the load.

The trench for receiving this pipe was first coated with 4 in. of beach or fine dune sand and after the pipe was laid the trench was backfilled with sand to the center of the pipe. The steel pipe was joined in the field with an electric lap weld. After a section of the line approximately 1,000 ft. long had been laid and the field joints welded, the ends were bulkheaded and tested for leakage under pressure of approximately 125 lb. After field testing, the joints were painted with a priming coat of asphaltum, followed by a heavy coat of asphaltic pipe dip. Reinforcing mesh was placed around the joint and the joint gunited. It was found necessary to have at least 30 in. of clearance all around the pipe at bell holes. Manholes were provided for painting the inside of the pipe at the joints as well as for the installation of air and vacuum pipes.

Where the line crosses Newport Bay, 24-in. flexible cast-iron pipe was installed.

The gravity portion of the line consisted of 18- to 27-in. diameter centrifugally spun reinforced-concrete pipe made as follows: Cylindrical steel forms made in two parts were used, supported in a horizontal position on power-driven rollers. Inside the steel cylinder was placed reinforcement designed for the head that the pipe is to withstand. Next the forms were rotated while concrete was shoveled into the cylinders. By rotation the concrete was uniformly spread over the inside. When the form had rotated a sufficient length of time all slurry consisting of lighter and latent materials was removed by means of brushes, after which the pipe was again revolved at a higher rate of speed and the inside of the pipe given a smooth finish by passing a rod back and forth over the interior surface. After spinning, the pipe was steam cured for at least twelve hours. The outside forms were then removed and the pipe cured for eight days by sprinkling. The pipe manufactured in this manner is much superior to poured-concrete pipe. On account of the high density obtained by rotating, the pipe has an increased tensile strength.



MANUFACTURING SPUN REINFORCED-CONCRETE PIPE

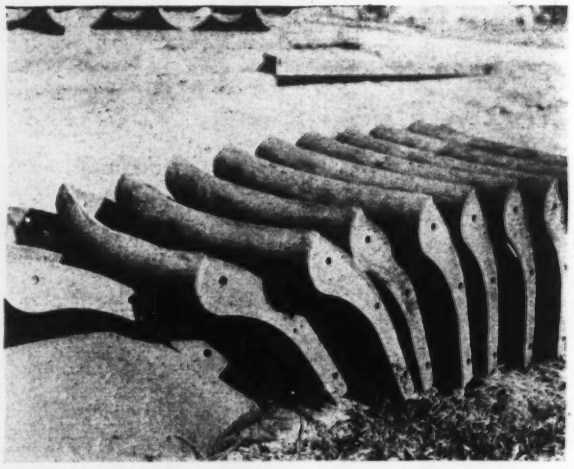
In designing the concrete pipe, sufficient steel was provided to carry the entire tensile stresses with a unit stress of 16,000 lb. per square inch. The minimum thickness of concrete shell was determined by using sufficient concrete to carry the maximum tension without increasing the tensile stresses in the concrete beyond 200 lb. per square inch, using a modulus of elasticity of 10 to 1. One of the important features of centrifugally spun concrete pipe is the type of field joint used. A spun collar 8 in. in width was calked on the end of each of the pipe sections in the contractor's yard before it was hauled to the side of the trench. The inside diameter of this collar was approximately 1½ in. greater than the outside diameter of the pipe.

Following Australian precedent (this type of spun pipe originated in Australia), an asphaltic collar was placed in a groove in the end of each pipe and then the pipe jacked into the section previously laid until the two sections were flush. Under this pressure it was intended that the plastic material would completely fill the concave ends of the pipe. The remaining space was next calked with a 1:1 mixture of cement and fine sand. It was the idea thus to provide for expansion.

After the pipe was laid the line was backfilled with fine sand up to the center of the pipe and then with

SUPPORTS AT "DRAW" FOR SPUN-CONCRETE PIPE

earth from the trench to a depth of at least 6 in. over the top of the pipe. It was then found that the plastic material was of no value in that during the time between laying and testing the pipe the plastic material would flow between the ends of the pipe and hang down into the interior of the pipe. This trouble was eliminated by using dry jute and calking with neat cement, the asphalt being eliminated. There was a little leakage



A CHARGE TO OBSOLESCENCE AT ST. LOUIS, MO.
Segments of cast-iron horse troughs stored in waterworks yards.

at the joints on testing. All joints which leaked were recalked with neat cement. After the joint had been repaired in this manner the line was again put under pressure and the leakage was but 20 per cent of the specified allowance of 200 gal. per inch of diameter per mile per day. The line has been in service more than two years and a recent test of its watertightness disclosed practically no leakage.

Table I gives the cost data for the gunite-coated steel pipe and Table II the approximate cost of the field operations for the concrete pipe.

The contract for the line was awarded to the H. W. Rohl Co., of Los Angeles and San Francisco. The steel pipe was fabricated by the Steel Pipe & Tank Co., of Berkeley. The gunite coating was applied by the Cement Gun Construction Co., of California. The centrifugally spun concrete pipe was made and laid by the American Concrete Pipe Co., of Los Angeles. The conduit design and construction was supervised by the engineering offices of J. B. Lippincott, of Los Angeles, and Roy Browning, engineer for the Irvine Ranch Co.

Before concluding, a few words may be said regarding water, soil and other factors affecting pipe lines in California. The local waters in California do not cause incrustation or tuberculation generally on the inside of steel and cast-iron pipes. However, our soils are more corrosive than others, and steel pipe has been quite generally protected by double dipping with a California asphaltum and by wrapping spirally with a paper similar to a good grade of roofing paper. This method of wrapping has been quite satisfactory where care has been taken in field inspection at the time of laying and joints have been properly wrapped in the field. All of the companies manufacturing riveted steel pipe in California are equipped to furnish wrapped pipe. This wrapping is generally furnished at an average price of 1½c. per inch of diameter. We are of the opinion that a gunited coating is superior to any wrapping for steel pipe yet perfected. It is more costly on account of the special equipment required and cannot be economically applied unless the pipe is of large diameter and there is a sufficient quantity of it to warrant setting up a special yard for guniting. A centrifugally spun pipe for heads up to 150 ft. makes an excellent long-life pipe and on account of its smooth interior, friction losses are materially reduced.

Distribution System Practices of a Large Group of Water Companies

How Central Engineering Department Deals With Mains, Services, Meters, Valves and Hydrants, and Some Remarks on Allocation of Yearly Costs to Maintenance and Replacement Reserve

By George W. Biggs, Jr.
Chief Engineer, Water Works Division, American Water Works & Electric Co., New York City

THOUSANDS OF PAGES have been written on water-works design and construction to one page on operation and maintenance. Distribution systems, the arteries conveying water through every street and to every building, have received scant attention in literature. This fact gives exceptional weight to the following article, because it summarizes years of experience gleaned from many water-works under the centralized control of the oldest large parent water company of the country. —EDITOR.

THE distribution system of the average water-works plant, including mains, services, meters, valves and hydrants, comprises approximately 60 per cent of the total cost of the entire property. The average cost of the operation and maintenance of the distribution system represents about 8 per cent of the total operating expenses of a privately owned water-works plant, including depreciation and all taxes, as compared with about 9.5 per cent for fuel or power when all the water supply is pumped. Much technical advice is frequently devoted to pumping equipment, but in many cases the distribution system is expanded without the necessary amount of care and study.

The distribution pipe system is usually largely composed of cast-iron pipe, jointed either with lead or with some substitute not requiring calking. A source of expense in maintaining the cast-iron distribution system is the repairing of leaks, replacing broken or cracked lengths of pipe and mechanically removing incrustation which most waters cause to form on the interior surface.

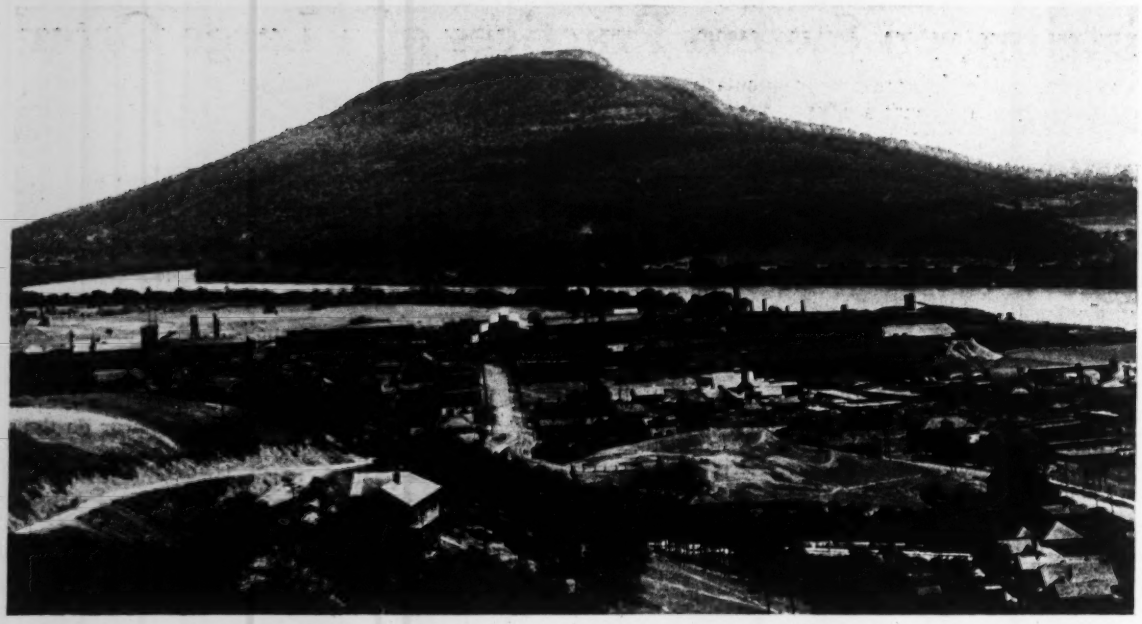
Pipe breaks usually result from a combination of stresses from bursting pressure on the interior surface and transverse stresses due to uneven bearing of the pipe on the bottom of the trench, or from settlement.

Leakage from the pipe system usually occurs at the joints, due to the fact that the joints originally were improperly made, or to the movement of the pipe in the joints, due to subsequent expansion and contraction.

Locating and repairing breaks in the pipe system is a comparatively simple matter, as the volume of water escaping from a broken or cracked pipe is generally sufficient to appear on the surface. Small joint leaks, which do not appear on the surface of the ground, particularly where the surface of the street is paved, present a different aspect, on account of the difficulty of locating them.

The 40 water-works in the United States and the two in Cuba (supplying more than two hundred communities), forming the group with which the writer is associated, compile quarterly a tabulation for each property showing the total amount of water sold and otherwise accounted for and the total unaccounted for, which represents leakage from the pipe system and service connections, under-registration of meters and evaporation and seepage from distribution reservoirs. The average unaccounted-for water for the entire group of water plants, owned and operated by the American Water Works & Electric Co. was 23 per cent for the calendar year 1929. The lowest record of unaccounted-for water for any plant of the group was 2.1 per cent, but at that plant more than 90 per cent of the total amount of water pumped is used by three industrial consumers located in close proximity to the distribution pumping station. When the quarterly check shows a marked increase in the percentage of unaccounted-for water, or where the departure is much higher than the average for a practically 100 per cent metered community, it

LOCATION OF WATER-WORKS PROPERTIES OF THE AMERICAN WATER WORKS & ELECTRIC CO., INC.



CHATTANOOGA FURNISHES WATER TO THE TOP OF LOOKOUT MOUNTAIN

The distribution system of the City Water Co., of Chattanooga, reaches to the top of this mountain of Civil War fame, 1,550 ft. above the Tennessee River, the source of supply, and supplies the community there located. Delivery is made by means of a booster pump through an 8-in. steel force main. The working head on the pump is 1,500 ft.

is the practice to conduct a leak survey to locate and repair undiscovered underground leaks.

In some of the larger plants permanent pitometer connections have been set in the main feed lines to determine the amount of water used in a particular district during the minimum-flow period, which is usually after midnight. Annual records are kept of the flow of water into such districts so that comparisons can be made from year to year to note any marked deviation from previous results. This practice has produced good results in keeping to a minimum the unaccounted-for water in such districts, and also furnishes valuable information in regard to the distribution of consumption.

Electrolysis Now a Minor Problem

Electrolysis of the distribution pipe system was a matter of considerable concern to the owners and operators of water-works properties some years ago. It soon became evident that the damage from electrolysis was generally confined to a few localities where the electric current drained from the pipe to some other conductor having less electrical resistance, so that the total maintenance cost for repairing damage caused by electrolytic action has not been a heavy burden. With the substitution of bus lines for electric railways in many smaller communities, so much in evidence in recent years, damage from electrolytic action is becoming less and less. Where electric street railways are still in operation, considerable benefit has been derived by the water, gas and telephone interests uniting and working with the street railway companies to reduce the amount of electric current conducted by the pipe system by the installation of return feeders paralleling the rails of the electric street railway company and by properly bonding the rails. To a limited extent overhead drainage of the pipe system has been permitted. This drainage should not be permitted until after all reasonable precautions have been taken by the electric street railway company to provide adequate facilities to return the current over its own rails and wires. The engineering department of the American Water Works & Electric Co. maintains an organization whose duties are confined to making electrolysis surveys and installing corrective facilities.

Possibly the reduction in carrying capacity by the formation of tubercles or incrustation of the interior surface of cast-iron pipe mains is the principal cause of worry and expense on the part of water-works managers. Most waters cause tuberculation to a greater or less degree, the single exception, in the experience of the writer, being the water from the Great Lakes. With increasing consumption in growing communities, and decreasing carrying capacity, resulting from tuberculation, after a term of years it becomes necessary either to remove the tuberculation mechanically or to install additional pipe capacity, even though the capacity of pipe system is adequate if it had not been reduced by tuberculation. The cleaning of the mains is usually the most economical course to pursue, and practically the original capacity of the mains can be restored by properly cleaning them.

Low alkalinity and high carbon dioxide (CO_2) content are the qualities of water which cause the greatest amount of tuberculation. By reducing or removing entirely the CO_2 from the water delivered into the pipe system, tuberculation can be greatly reduced, and, particularly where mains have been cleaned, such a remedial measure is of great importance.

Cement-Lined Cast-Iron Pipe Adoped as Standard

For approximately five years cement-lined cast-iron pipe has been adopted as standard for the subsidiary water-works plants of the American Water Works & Electric Co., with the exception of a few where the water is free from those qualities that cause tuberculation. Periodic examination has been made of the condition of the first cement-lined cast-iron pipe installed and, so far, the results prove it to be a very satisfactory measure for the elimination of tuberculation. The only deterioration

of the cement lining has been a slight leaching of the lime from the surface.

In some parts of the country, particularly in the South, where pipe is laid with a relatively shallow cover, it has proved economical to install 2-in. mains, to supply domestic consumers only. Until recently it has been the practice to use galvanized-iron or steel in such cases, but as pipes of those materials are subject to more or less rapid corrosion and incrustation, depending upon local soil conditions as affecting the outside and the quality of the water the inside, the cost of maintenance and replacement is necessarily high. Furthermore, when the streets in which such pipes have been laid are permanently paved, it frequently becomes advisable to replace the steel and wrought-iron pipe with cast-iron to avoid subsequent expense for making repairs and replacements on account of the additional cost of cutting and restoring the pavement. Very recently there has been adopted, for the group of American Water Works & Electric Co.'s plants, 2-in. cement-lined cast-iron pipe, which can be left in place under permanent paving without any more maintenance and replacement expense than cast-iron pipe of larger size. With cement-lined cast-iron pipe now being used for all sizes in the distribution system of our plants, pipe maintenance and renewal expense should be reduced to the very minimum for future generations of water-works operators.

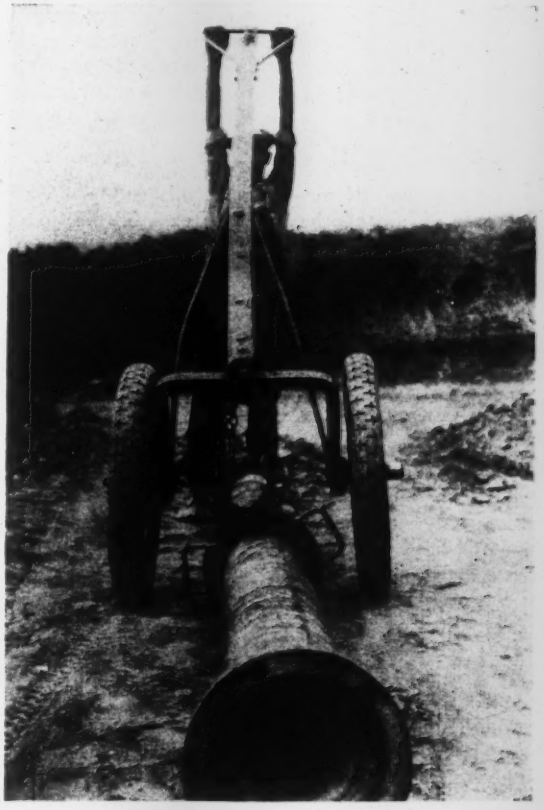
Accounting Problems

In most states the uniform classifications of accounts, prescribed by the state public service commissions, require the charging to maintenance of all expense for lowering and relocating mains. This constitutes a very substantial percentage of the total cost of maintaining the pipe system, particularly during the last ten years, on account of the increased activity in street grading and paving because of the postponement of much of such work during the war period. The increased use of automobiles has also resulted in more paving of streets and highways.

In the early days of water-works construction, particularly in the smaller cities, water mains were laid with but little regard for subsequent grading, due in part to the fact that such grades had not been established. With more comprehensive engineering on the part of municipalities, it is now generally possible to secure established street grades before the installation of mains. Usually it will be found economical to lay the mains at the proper depth below such grades, thereby avoiding the subsequent cost of lowering.

Experience shows that certain precautions should be taken in the design of a pipe system to avoid excessive replacement and maintenance costs. The use of wyes in pressure lines should be avoided. The standard design of a wye does not provide sufficient strength to take care of the large opening at the junction of the branch and the fitting. It has also been found by experience that the use of lead substitutes on tapping sleeves results in frequent breaking of the sleeves, necessitating replacements. Such breaks have not been noted with the use of lead, which is more flexible than the substitutes now on the market. On account of the likelihood of hydrants being struck by automobiles, it has been found advantageous to use lead instead of a substitute where the hydrant branch is joined to the hydrant hub. It has been the writer's further experience that the use of lead substitutes for joints laid under railroad and street-car tracks is less desirable than lead, on account of the jar to which they are subject. Proper installation of mains under tracks, at a greater depth than pipe is ordinarily laid, will also reduce maintenance expense at these points. In certain soils sometimes the use of special split bell sleeves or joint clamps is warranted under railroad and street-car tracks.

Perhaps in no other part of a water-works plant is it more difficult to distinguish between the proper charge to maintenance and that to the replacement reserve than in the distribution system. Many years ago it was recognized, in the group of plants with which the writer is associated, that there was no uniform method of allocating such expenses. To clarify this situation, rules were established, many of which were necessarily arbitrary, to allocate charges properly to maintenance and to depreciation. A general rule established was to charge the depreciation reserve with the original cost of the unit of property, when replaced, and the maintenance expense with the cost of maintaining a unit of property in serviceable condition during its period of existence. Except for the distribution pipe system, a unit of property can usually be easily defined, but obviously some arbitrary distinction is necessary in the case of a pipe line made up of many joints of pipe. The rule established in the writer's practice is to charge against the depreciation reserve the replacement of a section of more than one length of pipe, the replacement of a fitting or special, a valve or a valve box. All other expenses are charged to maintenance or operation.



CART FOR DELIVERY OF LARGE PIPE TO TRENCHES
Used by Huntington (W. Va.) Water Corporation.

In most parts of the country galvanized-iron or steel services were standard practice in the early construction

of water-works plants. On account of high maintenance and replacement cost, particularly with the general paving of streets, it became evident that a more durable material for services was advisable. For many years lead services have been used, connected to the corporation cock either by wiped joints or, more recently, by lead-flanged connections. Within the last few years copper services, with especially designed joints for making connections, have been largely adopted. It is the writer's opinion that the choice of lead or copper depends on the relative cost of installation and that there is little difference between the two as to durability and maintenance cost. The substitution of lead or copper for galvanized steel and iron services has resulted in much lessened cost for maintenance and replacement, and as the old iron services are gradually replaced the cost of maintenance and replacement of services will gradually become less.

Meters a Large Item in Distribution Expense

The maintenance of meters in a fully metered water-works plant is one of the largest items of distribution expense. In some states the public service commissions prescribe certain specified periods for testing the accuracy of the registration of meters. Where no such rules are prescribed by regulating bodies, it is the custom, in the writer's experience, to remove, test and repair all meters in the system in a certain number of years, which varies with the character of water passing through the meters. In some places it has been found necessary to test and repair all meters within periods of from two to three years, and at other places periods of from five to six years, or even longer, are sufficient. Some waters require a modification of the standard meter design in certain respects in order to avoid excessive maintenance cost.

An item of substantial expense in meter maintenance is the freezing of meters, whether located in boxes at the curb or in the cellars of buildings. The freezing of some meters in extremely cold weather appears unavoidable. In the South, where occasional extremely cold weather occurs for short periods, trouble from freezing is more pronounced, on account of the lesser depth at which mains and services are laid. The general use of breakable cast-iron frost bottoms keeps the cost of repairing frozen meters to the minimum.

The location of meters, whether in a box at the curb or in the cellar of a building, affects the operating and maintenance expenses. Except in extremely cold climates, meters installed in properly designed boxes at the curb show a less percentage frozen than where set in cellars. The cost of reading meters is greatly reduced where they are set at the curb, and the curb setting has a further advantage of securing the registration of leakage from the service line between the curb and the building. While there are some disadvantages in setting meters at the curb, they are, in my opinion, far outweighed by the advantages in reduced operating and maintenance expenses as compared with installations in the cellars.

Valve Inspection and Records

The cost of maintenance and operation of valves and fire hydrants is relatively unimportant.

Gate valves in a distribution system are infrequently operated in regular routine procedure. Therefore it is very desirable that at definite intervals each valve in the distribution system be operated to ascertain its condition and that such repairs be made as may be shown necessary, also to insure that all valves in the system which should be open are wide open, as it not infrequently happens that after making repairs or connections certain valves are inadvertently left closed that should be open. It is also desirable, in testing the valves, to count the number of turns to make sure that they are wide open. The occasional operation of valves will remove the tubercles which frequently form on the cast-iron body of the valve between the seat rings, which, if allowed to accumulate for a long period of time, make it impossible to secure a tight shutoff. An accurate permanent record should be kept of each valve in the system, with dimensioned references from well-established points, so it can be readily located when the street is covered with snow and ice. Such references are also important the year round where there is no pavement, as then the top of the valve box is likely to be below the surface of the road.

LAYING PIPE FOR BIRMINGHAM WATER WORKS CO.
A 42-in. concrete pipe being lowered to place by the shovel that dug the trench.

It is of the utmost importance that all valves in the distribution pipe system open and close in the same direction. It has been frequently found in some of the older plants that the original purchases were made without regard to the direction of operation. Where such valves exist, the stems and wedge nuts should be changed in order to secure uniform direction of rotation. Valves closing in different directions increase maintenance expense because of valve stems being twisted off in attempting to operate them. Good water-works practice requires the operation and inspection of each fire hydrant at least once and preferably twice each year. It is the writer's practice to require the operation and inspection of each hydrant before freezing weather. The inspection consists of opening and closing the hydrant to make certain it is in operative condition; to ascertain whether or not the hydrant drains properly; to grease the nozzles and inspect the threads on the nozzles; calk the lead joint, if necessary, where the nozzles are attached to the hydrant barrel; replace any missing hydrant caps and chains and repack the stuffing box, if necessary. If hydrants are located in ground so that they cannot drain through the bottom drip, the practice is to plug the drip and pump the water out of the hydrant

barrel. In all such cases, during freezing weather frequent inspections are made and the water is pumped out as often as it accumulates from possible leaking hydrant valves. It is always the practice, in addition to the regular annual or semi-annual inspections, to operate and inspect fire hydrants after each time they are used by the fire department.

Fire hydrants should be kept well painted, using a color to increase the visibility in order to avoid delay on the part of the fire departments in locating them when there is a conflagration.

The engineering department of the National Board of Fire Underwriters has for several years been conducting a campaign to get all fire hydrant threads standardized. This is a very laudable aim and as far as possible the water companies and departments should co-operate, notwithstanding the additional expense incurred. In practically all instances the threads on nozzles which are other than standard can be rechased with tools which can either be borrowed from the National Board of Fire Underwriters or purchased at a nominal expense. The advantages of such standardization are that fire departments from different cities can connect to such hydrants without the use of adapters, which would not be readily available, and prevent possible errors in ordering as might be the case where threads of different dimensions are specified.

The principal cause of damage and maintenance and replacement expense of fire hydrants is accidental breakage from automobiles and motor trucks. On account of this hazard, all hydrants should be placed far enough back from the curb so that the wheels of any motor vehicle will strike the curb before any projecting part can come in contact with the hydrant. It is also advisable to set hydrants back from the corner a sufficient distance so that they will not be damaged by automobile going over the curb lines when turning corners, as sometimes happens when careless or inexperienced drivers are at the wheel.

Obsolescence Small Factor in Distribution Systems

Perhaps the design and construction of the distribution system of a water-works plant has undergone less change, with the passing generations, than any other engineering project. Cast iron is still used almost exclusively for the distribution mains. The cast-iron pipe joints are being made in the same way as they have been for generations. Only slight changes have been made in the design of meters, hydrants and valves. Obsolescence touches but lightly in direct contrast to most human endeavors. The distribution systems of the earliest constructed water plants in this country are still largely intact, and it would require a stretch of the imagination to discover in them an appreciable amount of obsolescence or depreciation.

Tuberculation of asphalt-coated cast-iron water pipe has been its greatest enemy. With this trouble overcome by lining the interior surface with cement or some other protective lining and with the substitution of cast iron, lead and copper for less durable materials for small mains and for service connections, the distribution system of a water-works plant becomes practically permanent, involving a minimum of expense for maintenance and renewals, if properly installed.

Submerged Water Main of 8-In. Reinforced-Rubber Pipe

Laid on Creek Bed at Draw Span to Connect Fixed Cast-Iron Main Supported by Portion of Bridge

By Walter C. Munroe

Chief Engineer, Anne Arundel County Sanitary Commission, Glen Burnie, Md.

RUBBER pipe of 8-in. internal diameter, reinforced with embedded steel wire, was recently used for a submerged water main that had to be put down in a hurry to provide water for a typhoid-stricken village in Maryland. The job was done quickly, at little cost, and the pipe has given satisfaction. Details of the occasion for this unusual piece of work and of how the pipe was made and laid follow:

During the summer of 1928 a serious outbreak of typhoid fever occurred in Eastport, Md. The state department of health assumed immediate charge of the situation and promptly arranged with the Anne Arundel County Sanitary Commission for the construction of a water-distribution system within the stricken village, to serve some 500 dwellings. At that time all were drawing water from individual wells, which were unquestionably responsible for the rapid spread of the disease throughout the city.

The nearest source of supply lay in the city of Annapolis, separated from the area affected by Spa Creek, a body of salt water spanned by a highway bridge 950 ft. long with a swing draw 115 ft. wide, located near the center of the stream. Careful soundings and investigations revealed an average depth of 11 ft. of water, with a bottom of ooze and muck to a depth of some 40 ft.

It was at once apparent that the bottom could not support even the lightest of metal pipe, and rather than provide pile foundations throughout the entire distance of 950 ft. it was decided to keep as much of the pipe as possible above water. Accordingly a 12-in. main was laid, from both shores to the drawspan, upon beams fastened to the bridge members. At this point it became necessary, in order to permit vessels to pass the drawspan, to lay submerged pipe on the bottom.

It must be remembered that time is a most important factor in cases of this kind and that time-consuming methods are to be eliminated not only because of high cost but because delay may cost human lives. Careful investigation at the drawspan showed the bottom to be as bad as or worse than at other points where tests were made. There were also numerous obstructions, including quantities of large rock piled around the center pier, presumably placed there to support the draw. Pile and timber fenders extending up and down stream, old sunken timbers, and broken-off piles, remaining from a former highway bridge, presented further difficulties to the laying of submerged metal pipe supported by piles. To pass the obstructions just mentioned it became necessary to pick a definite path which assumed a curved line and increased the necessary length of the pipe line by 30 ft., making its total length 150 ft.

Government authorities specified that metal pipes should be buried not less than 4 ft. below the bottom. Such procedure would have made the project a slow and tedious undertaking, because the character of the bottom is such that there is no stability and a great amount of material must be removed in order to excavate a trench

5 ft. deep. After that had been accomplished, there still remained the difficult and somewhat uncertain work for the divers to perform.

The difficulties noted, together with winter weather, were fully reflected in the proposals, both as to cost and as to time for completion, and therefore the orthodox methods for making the installation were abandoned for swifter and more economical methods.

After careful consideration of the various kinds of pipe and materials readily available, it was decided to investigate pipe fabricated from rubber. A hurried visit to the main plant of one of the largest manufacturers of rubber materials resulted in a conference with its engineers and specialists and definite assurance that pipe of the required diameter in lengths up to 50 ft. could be fab-

RUBBER WATER MAIN READY TO BE LAUNCHED
Half of 150-ft. length. Note bulkhead on near end of pipe.

ricated to withstand any pressure and could be armored against external damage. The only definite information as to the probable life of the material was contained in statements covering the examination and analysis of rubber hose and other rubber products recovered from sunken vessels or otherwise where it had been submerged in salt water for periods varying from a few years to more than twenty years. In all cases mentioned there was little or no deterioration of the samples examined, and the general opinion of the manufacturers was to the effect that submerging rubber pipe was the ideal condition for its preservation.

It was, therefore, decided to use pipe of this character, and the remaining question of taste and odor arising from chlorinated water in contact with rubber proved a serious problem and necessitated much experimental compounding at the factory before a lining was produced that proved to be suitable.

The pipe was fabricated by the Goodyear Tire & Rubber Co., Akron, Ohio, as follows: 8-in. internal diameter, side walls 1⅛ in. thick with 0.283-in. diameter copperized-steel wire wound spirally at ⅝-in. spacing and embedded about ½ in. from the outer circumference. The pipe was manufactured in three 50-ft. lengths and fitted with standard cast-iron flanged couplings, the flanges being cast integral with beaded nipples, which were built into the pipe. As an extra precaution, heavy navy bronze clamps were fastened over the nipples and made up tight before installing.

The three 50-ft. pipe sections were jointed on shore and the couplings covered with a special waterproofing material applied hot over a coat of priming. The pipe was then towed, with the ends made watertight, to the drawspan and fastened above water: one end to an ell at the foot of an 8-in. vertical drop pipe, after which half of the pipe was lowered to its resting place upon the bottom, by filling it with water from the 12-in. main already in place. A water jet was used to sink the pipe in the soft bottom.

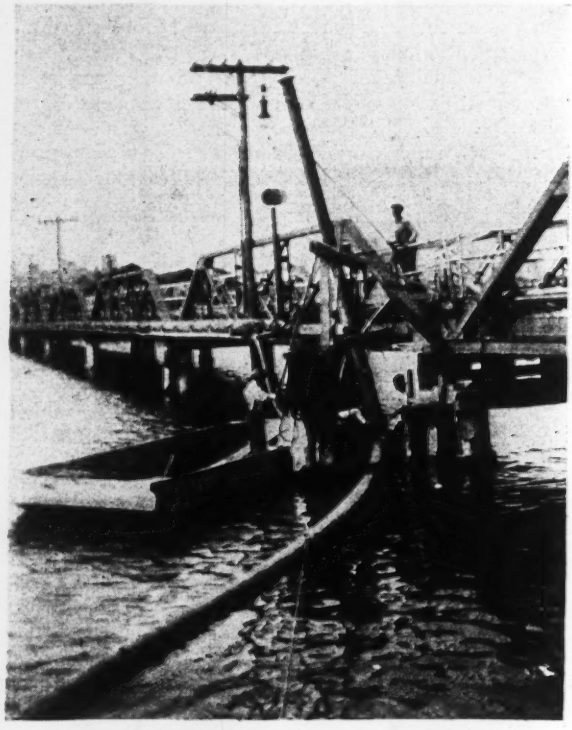
During the lowering of the first half the remaining pipe was floated upstream and held clear of navigation passing through the drawspan. The free end was then floated into place and lowered in the same manner. The final joints at the tops of the vertical drop pipes were made up to the main on the bridge structure, and the job was then complete. The entire operation was quite simple and inexpensive and required a minimum amount of time.

Soundings, after the rubber pipe had been several months on the bottom, show that the ooze has sufficient bearing to support pipe of this character, although uneven settlement would be of no consequence.

The entire line or half at a time can be raised for inspection by disconnecting it and pumping it full of air.

The cost of the installation below water, including all materials and the removal of old bridge timbers and refuse, was $1,250.

The War Department waived the requirement, applicable to metal pipe, that the rubber pipe be sunk to



LOWERING RUBBER WATER MAIN FOR SUBMERGED CROSSING
At bridge, rubber pipe is attached to cast-iron ell on lower end of vertical cast-iron riser; latter to be connected to horizontal run of cast-iron pipe supported by bridge. Rubber pipe, when lowered to bottom, and connected with its twin, forms a loop to pass around obstructions in riverbed.

a depth of 4 ft., since this kind of pipe is not considered to be a permanent obstruction, as it can be raised, moved laterally and, on occasion, lowered again by jetting, as was done when the pipe was first laid.

It would seem that the use of pipe of this character has possibilities for submerged work, and while many engineers will voice immediate disapproval when it is mentioned in connection with permanency, time alone will probably give the only correct answer.

Meter Installation and Operation Practice

Percentage of Metered Water Growing While Types of Meters Persist but Are Refined —Usually Customers Maintain but Do Not Own Meters—Value of Periodic Testing Questioned

By H. P. Matte
Manager, Meter Division, Worthington Pump & Machinery Corp., Harrison, N. J.

MULTIPLE TEST STANDS FOR SMALL METERS

METER PRACTICE, as seen by the engineer of one of the oldest manufacturers of water meters, is a subject seldom if ever before treated in print. This, combined with the constantly growing use and importance of the meter, should make Mr. Matte's article one of broad appeal. —EDITOR.

DURING the past 50 years the water meter has played a very important part in the constantly improving technique of water-works operation. In the face of early indifference and adverse propaganda the number of meters has increased by leaps and bounds, until the meter has become the almost indispensable servant of every community having a public water supply. This may seem to be an extravagant statement, but there are few cities which do not at least have industrial meters.

If the interested searcher through the history of American water-works practice will go back no farther than 30 years, he will find that an average of only 25 per cent of the services in a group of a hundred of the larger cities was metered. Today the same list of municipalities can boast of an average of at least 80 per cent of the services on a metered rate. A most significant fact is that no city which adopts the meter system ever returns to selling water by the flat rate.

Some Large Cities Still on Flat Rate—A few of the most densely populated cities, however, still retain the flat-rate system for the majority of the domestic services. The larger municipalities in the United States which have not as yet officially adopted universal metering are New York, Philadelphia, St. Louis, Baltimore, Buffalo, Denver and Pittsburgh. Reasons advanced for this condition range from popular objections to paying for water that is used and the natural reluctance on the part of city officials to force consumers on old services to pay for meters and the cost of installation, to financial reasons for not metering en masse at the expense of the municipalities. Chicago may yet be considered as belonging to this group, but the fact that an ordinance has been passed to effect the complete meterage of that city permits the conclusion that universal meterage has been officially adopted.

Notwithstanding the present difficulties, the water-works executives and engineers in the cities just named are aware of the value of metering and are placing meters in new residences, where this is possible and is not prohibited by ordinances, and are encouraging the voluntary metering of old and new services. All business and industrial services are metered in these cities.

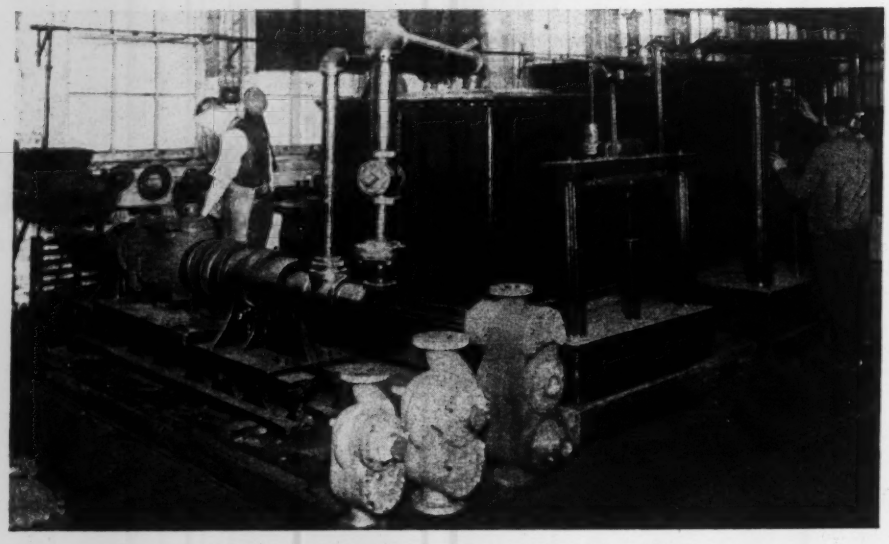
Metering in the Country at Large—Analyses of the extent of metering often seem to neglect the numerous smaller cities, towns and villages. There are many efficient small water-works systems in the United States, and as the small cities are more numerous, they certainly have an important bearing upon general statistics.

Accurate records are not available, but it seems that at least 65 per cent of the population on public water-works

systems in the United States is, in cities at least, 70 per cent metered. To continue this analysis still further, by eliminating seven very large cities which have a notable smaller percentage of their population metered, we might estimate at least 80 per cent of the remaining public water-consuming population in this country is located in cities that are more than 70 per cent metered. These figures exclude all the commercial and industrial metered services that can be segregated.

Apparently there are only seven states that do not have a preponderance of cities with more than 70 per cent of their population metered. However, these states have relatively few water-works. The states of the far South and Southwest are particularly well metered, and all the large, level Middle West states are strong for complete meterage. Cities in mountainous regions which offer plenty of good water without the necessity of treatment and sometimes without pumping are not prone to meter on a large scale.

Development and Standardization of Meters—The first meter used on a water-service connection was a duplex piston meter set in the late '50s. Other types of piston meters followed. The disk meter began to be used in the '80s. Today the standard meters used for cold water services are the disk, the oscillating piston, and the turbine, and those meters compounded with turbine meters. Many of the old piston meters are still in service on a few systems.



TESTING LARGE METERS BY WEIGHING TANKS

It is a notable fact that water meters, particularly of the disk types, have not undergone any radical changes in principle, design or construction during all these years. It is true that capacities have been increased for the same size of meter and that frost protection and oil-inclosed trains have appeared. We can assert, too, that the workmanship and accuracy of registration have improved, but in general the original types still remain with us.

The outstanding improvements in meter manufacture have been in workmanship and standardization, and the latter has been brought about in the United States only since the World War. It was accomplished after a series of conferences by the American Water Works Association and the New England Water Works Association in co-operation with the standardization committee of the meter manufacturers. The standard specifications, which cover over-all dimensions, construction details, materials, accuracy and capacity requirements, were adopted by the water-works associations in 1921 for disk meters and in 1923 for turbine or velocity meters.

Prior to the adoption of these specifications there was naturally a tendency toward wide divergence as to what constituted an acceptable meter. Lengths of spuds and threads varied, couplings differed in length and design. There was no agreement as to test requirements. This confusion worked a hardship not only on the meter manufacturers but also on the water-works. At present the most important meters, from the standpoint of numbers in service, are interchangeable and there is a strong tendency toward universal adoption of the standard specifications in their entirety.

Who Purchase and Own Meters—While the great majority of water-works purchase and own the meters, about 20 per cent of them require consumer ownership, although in most cases the meter is purchased by the city. It seems to be the general practice to require approval by the municipality even where the consumer purchases the meter.

Of the first 30 large cities in the country the owner or consumer pays for the meter in New York, Philadelphia, Los Angeles (3-in. and larger), Pittsburgh, Milwaukee, Newark, Minneapolis, Cincinnati, Kansas City (Mo.), Denver, Toledo, Columbus, Providence, Omaha, Atlanta and Akron (2-in. and upward). In New York, Philadelphia, Cincinnati, Milwaukee, Newark (N. J.), and Pittsburgh, the meters are purchased directly by the consumer or householder, although they are approved and tested by the municipalities before installation by the owners. Minneapolis purchases the meters, but requires the owners to install them. Newark charges a fee for each meter tested, the fee being according to size.

In the country as a whole, the present trend is toward municipal ownership of meters.

Charging for Maintenance—There is also a difference of opinion and practice with regard to the maintenance of meters, although the general practice is for it to be done by the municipalities or water companies. There is consistent uniformity in requiring the consumer to pay for repairs to meters rendered necessary by damage from heat, frost and violence, all of which are considered acts of negligence.

In the 30 largest cities of the country, those which require the owner or consumer to pay for repairs are New York, Philadelphia, Newark, Minneapolis, Cincinnati, Kansas City (Mo.), Denver, Toledo, Akron (2-in. and up) and Omaha (1½-in. and up). New York City does not repair meters. This work is done by several private companies, but the meters must pass the New York City water department's test before they may be reinstalled.

Testing Meters Before Acceptance—It has gradually become the custom for all the large and nearly all the medium-sized cities to test meters before they are

accepted for setting, and the practice is growing among the small municipalities. Tests vary in severity, although most water-works have adopted, either in whole or in part, the specifications recommended by the American and the New England water-works associations. Meters are tested singly for the most part, although several cities make use of multiple stands; for instance, New York tests five ⅝-in. meters at one time. Philadelphia increases this number to twelve.

Setting Water Meters—The practice of setting meters varies. In many cities plumbers or contractors install them, although the trend is toward the setting of the meters by the water department or company. In any case, meters are inspected and sealed by water-works employees. For the country as a whole preference is about evenly divided between setting meters in basements and in curb boxes. The practice in the South is usually to place the meters in the ground, protected by a shallow box.

Periodical Testing and Overhauling—The practice of inspecting and retesting meters after they have been in service for some specified number of years is often the subject of discussion. There seems to be a wide divergence of opinion, however, as to the justification of this additional expense of operation. The consensus of opinion apparently leans toward the conclusion that the saving does not warrant the expense, owing to the fact that the costs of removing, testing and replacing the meter are greater than the resulting benefits. At any rate very little of this is being done. Some of the states prescribe that meters be removed and tested at stated intervals, or after the passage of a certain quantity of

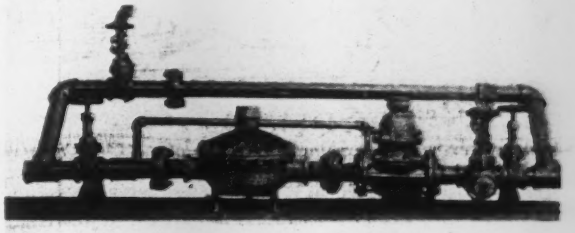
METER SHOP IN A SMALL CITY
Unpretentious though they may be, there are hundreds of shops of this kind which care for testing and minor repairs.

water. The time of service prescribed varies between five and ten years. Such rules generally apply to water companies only. A few municipalities have adopted definite schedules, but the great majority of water departments remove and test meters only when they stop for various reasons, or obviously slow up, or upon request of the consumer. In this last case the general rule is for the consumer to be required to pay a small charge if the meter proves upon test to be within the required limits.

Reading Meters—Quarterly readings of domestic meters lead over monthly readings by three to one. The principle of reading meters every month is preferred by many water-works men, because there is thereby an opportunity givn the consumer for the discovery of leaks, which cause high bills. The bills may be sent out quarterly, even though the meters are read monthly. In a few cities meters are read once in six months. Industrial meters are read monthly or weekly even where the domestic meters are read quarterly.

Meter readers are often considered contact men, and notify the consumer if the reading is abnormally high, in a large number of cities, whether the water systems be operated by private companies or municipalities.

Records for Billing—Accounting systems designed to handle meter accounts more expeditiously at less expense have gradually been introduced during the past fifteen years, keeping pace with the improvements found



BYPASS METER INSTALLATION WITH TEST TEE
The large disk meter is compounded with smaller meter. Used in Newark, N. J.

in other types of utilities. The old ledger book has few advocates among progressive water-works executives and accounting departments. Various types of billing and accounting machines have been developed to accommodate the needs of public utilities which are designed to meet the requirements of both small and large works. Both the card system and the stub system are in use, although the practice of eliminating all but the meter readers' books and using the stub or duplicate bill as a record, is gaining headway.

Continuous Billing—Whereas in the old days a certain period in the month or quarter was one of undue activity and one necessitating large forces to complete the billing on time, the gradual adoption of a number of districts for meter reading and billing has made this function an orderly and less expensive procedure for the large progressive water systems. Meters are read continuously and bills are rendered at different periods for each district.

American Water Meter Institute—This article may well be closed with a mention of the activities of the American Water Meter Institute, which is composed of manufacturers of water meters. This organization has for its purpose the elimination of practices and methods detrimental to the entire water-works industry, and the promotion of the further acceptance of the present standard specifications adopted by the water-works associations, so that the members of the Institute may be protected against unnecessary changes in formula of materials or changes in design and construction, unless and until such changes are warranted by the progress or needs of the industry and to eliminate unreasonable specifications and guarantees. The Institute has functioned a little over two years with almost 100 per cent membership, and manufacturing standards have been preserved to the benefit of the water-works fraternity. Close co-operation is maintained with the standards committees of the several water-works associations.

Selective Metering Considered Economical in St. Louis

Consumption Surveys Show Reasonable Use on Most Services—Household Waste Kept Down by Careful Inspection

SELECTIVE metering—that is, installing meters on only those services whose owners use a very large amount of water and in those districts where water waste is excessive, is considered to be the most economical method of eliminating wasteful consumption in St. Louis. This conclusion is based upon an analysis of data obtained from water-consumption surveys conducted during the past two years. Although consumer charges are

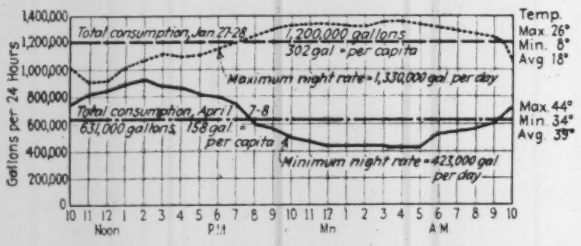


FIG. 1—EFFECT OF FREEZING WEATHER ON NIGHT WATER CONSUMPTION IN RESIDENTIAL DISTRICT

based largely on a flat rate, the domestic consumption is at a reasonable figure in most sections of the city. The number of faulty plumbing fixtures is kept down to a minimum by careful and regular inspection.

During the year ended April 1, 1929, water was pumped through the distribution mains at an average rate of 118,000,000 gal. a day (118.4 m.g.d.), or at the rate of 129 gal. per capita per day, based upon an estimated population of 918,000. Services in use total nearly 145,000, ranging in size from $\frac{5}{8}$ to 12. in. in diameter, and of these only a little more than 11,000, or about 7.7 per cent, are metered. All industrial establishments and other users of large quantities of water are metered. Of the income from water sales, 43.1 per cent is from metered customers.

Deducting from the total amount supplied the city the amount known to be used by industry and the small amount known to be lost through pipe line leakages, the gross domestic consumption is found to be about 80 m.g.d., or 87 gal. daily per capita. This figure includes the amount estimated to be wasted in household use and also the waste occasioned by allowing faucets to run continuously during freezing weather. If the waste items were to be eliminated entirely, the domestic consumption would be reduced to 67 m.g.d., or about 73 gal. daily per capita.

The foregoing statistics give a picture of the water consumption of the city as a whole, but the 13 m.g.d. by which the consumption could be reduced is not distributed uniformly throughout the city. Many sections show a use of water little greater than what should be expected were all items of waste to be eliminated. A large part of the city's population is made up of people of German birth or extraction in whom the characteristics of thrift and frugality are deeply inculcated. To such consumers the use of water is subjected to the same test of reasonable necessity as is that of other household commodities. Waste in any form is inherently distasteful, and the noise resulting from a leaky plumbing fixture is disagreeable.

TABLE I—DISTRIBUTION OF HOUSEHOLD WATER WASTE

Class	Household Waste: Ratio of Waste to Consumption	Household Waste: Per Cent of City Total	Household Waste: Per Cent Cumulative	Population: Per Cent of City Total	Population: Per Cent Cumulative
1	More than 25%...	50.5	50.5	19.5	19.5
2	15% to 20%.....	12.6	63.1	7.3	26.8
3	10% to 15%.....	19.0	82.1	22.3	49.1
4	5% to 10%.....	9.0	91.1	12.3	61.4
5	Less than 5%.....	8.9	100.0	38.6	100.0

The total amount of wasteful consumption under the direct control of the householder, 13 m.g.d., is made up of 7 m.g.d. household waste, including the effects of faulty plumbing, and 6 m.g.d. caused by allowing faucets to run continuously during freezing weather. With universal metering doubtless ordinary household waste would be eliminated, but it is improbable that metering would have any marked effect upon letting water run to prevent freezing of service pipes.

In studying the distribution of this 7-m.g.d. household waste among the 91 districts into which the city has been divided during the consumption survey, there was computed for each district the ratio between the amount of waste and the net domestic consumption. The districts were then grouped in five different classes according to the value of that ratio. Table I, giving the essential data for each group, shows that metering the water delivered to only 19.5 per cent of the city's population would result in eliminating 50.5 per cent of the total household waste of the city. Installing meters in the districts comprising the last group would save only 8.9 per cent of the total waste, although representing 38.6 per cent of the population.

The blocks, and in most cases the individual services, on which meters can most profitably be installed, are

TABLE II—MONTHLY WATER WASTE AND LEAKAGE RECORDS AT ST. LOUIS, 1929-30

Month	Number of Inspections	Notices Served on Account of Leaks: Toilets	Faucets	Service Pipes	Hydrants	Street Valves	Miscellaneous	Total	Leaks Reported by: Inspectors	Telephone	Pitometer Crews	Shut Off for Non-Repairs
1929												
April	22,233	943	421	158	48	13	26	1,589	1,101	119	369	1
May	20,499	1,305	507	152	60	31	18	2,073	777	140	1,156	3
June	23,035	1,477	587	185	81	17	28	2,375	958	154	1,263	2
July	20,788	1,479	601	148	40	9	28	2,305	930	173	1,202	5
August	20,257	1,085	548	214	42	18	41	1,948	1,559	216	173	2
September	16,311	939	522	169	27	6	28	1,691	1,151	161	379	5
October	12,024	729	368	209	31	12	34	1,383	437	212	734	8
November	9,021	590	268	173	36	20	36	1,123	768	193	162	3
December	7,991	507	213	316	15	3	21	1,075	792	283	...	1
1930												
January	7,926	323	172	280	20	11	32	838	521	317	...	8
February	10,689	515	218	286	22	9	24	1,074	795	221	58	2
March	14,027	831	294	182	18	5	32	1,362	507	150	705	2
Total	184,801	10,723	4,719	2,452	440	154	348	18,836	10,296	2,339	6,201	42

known. It is evident that metering, to whatever degree is desired, should start where the return would be largest for the investment.

To maintain a reasonable rate of water consumption on unmetered services the city has about 30 inspectors, whose duties consist of making constant and regular patrols of the householders' equipment and of calling to their attention and to the attention of the water department all leaky fixtures and wasteful use of water. During the year ended April 1, 1930, these inspectors made a total of almost 185,000 inspections, finding 18,836 leaky fixtures. Upon the report of such a leak, the consumer is notified by the inspection department and instructed to make repairs immediately. A second inspection is made ten days later to ascertain whether or not the necessary repairs have been completed. Five more days are allowed for the remedy of the situation before the water is shut off. The effectiveness of the inspection and notification system is attested by the fact that during the year there were only 42 services shut off for non-repairs.

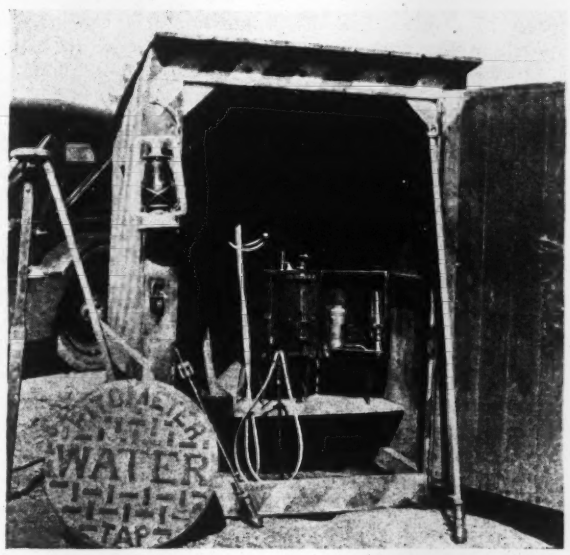


FIG. 2—PITOMETER IN USE AT ST. LOUIS
Note lamp used in making photographic record of manometer indications.

Table II shows the number of inspections and leaky fixtures reported during the several months of the year just completed. It is interesting to note that more than 2,000 leaks were reported to the department by the householders themselves over the telephone. The purpose of such a report is probably to force upon the attention of the landlord the unsatisfactory conditions experienced by the tenant.

A study of the experiences of the leak inspection department in conjunction with the results of the survey of consumption makes it appear to the engineers of the water department that St. Louis should exercise care in the selection of the house services upon which to install meters in order that the greatest economy will result. Such conclusions are dependent upon an efficient inspection personnel and a naturally frugal population such as St. Louis has.

Leak inspections, consumption surveys and meter installations are carried out under the supervision of T. J. Skinker, engineer in charge of distribution, reporting to L. A. Day, water commissioner.

Financing Municipally Owned Water-Works Systems

Capital Account, Charges for Water, Year-to-Year Budgetary Control and Long-Term Capital-Outlay Program

By Howell Wright

Attorney-at-Law; Formerly Director of Utilities for the City of Cleveland, Ohio

No Phase of water-works administration is more slighted than proper financing. When serving as director of Cleveland's water and light utilities Mr. Wright took an advanced stand on their financing. His ideas, as applied to water-works, are elaborated in what follows. —Editor.

THE fundamental principle to be followed in financing municipally owned water-works is that they should be self-supporting but not be called on to support other branches of the municipal service or to produce a profit to be used in the reduction of general taxation. To this end it is necessary to know what the capital account should include, how the burden of supplying water is to be divided between the public as a consumer and beneficiary on the one hand and private consumers on the other. Other prime essentials are budgetary control, including a long-term program for capital outlays.

The capital account should theoretically include all assets used in the business which have a life of two or more years. Circumstances should govern the proper method of handling such accounts. If there are proper tool-room facilities, tools may be carried as assets, but if not, and if they are therefore likely to be mislaid or stolen, they should be charged to expense. Services and meters—which should be provided and paid for by the city—should be carried as assets.

A study of the financial history of most publicly owned utilities will show that every method of financing has been resorted to at some time or other. The ideal method of financing a publicly owned utility is the "pay-as-you-go" plan. This method is not always feasible, especially in the early years of business. It is at first necessary either to issue bonds or to lend or give the utility sums from the general fund or to levy special assessments on property benefited. If the utility is supposed to be on a self-supporting basis, general taxation cannot be used as a source of revenue. Extensions of mains may be financed by assessments on benefited real estate or by charges against water users.

Profits made from the sale of the product should be reinvested in the business. This reinvestment may be done by retiring bonds already issued or by using the money for extensions, thereby eliminating borrowing.

If political considerations permit such a water rate as will make possible the payment for all extensions and betterments from revenue the ideal would be attained, because in such a case there would be no interest charges and consequently only three items of expense—operation, maintenance and depreciation.

The question of how to finance assets used in supplying other municipalities is easy to answer in theory but hard in practice. Theoretically, enough profit should be made from each municipality to pay for all such present and future assets. Practically, this is not always possible. If the cost of the product were charged the rate would be prohibitive, resulting in little or no sale. There-

fore, from a practical standpoint, all financing costs for assets used in supplying other municipalities should be charged against them if possible. If this is not possible, the largest collectible amount should be charged and the balance may be charged later either through high-rate schedules or high stand-by charges.

In order that the water consumer shall be charged an equitable amount for his own personal water supply the municipality should pay some of the costs of the service, because some of the equipment is used for fire protection and other public uses. What percentage of the total cost should be borne by the city because of these uses is a question for which no standard answer has been given. Some authorities maintain that the city general fund should pay what is called the stand-by cost. This cost is made up of the fixed charges on all water mains and hydrants, and maintenance of hydrants and a small proportion of the fixed charges of the pumping stations and other equipment, together with an estimated amount that would represent the amount of water used times the standard rate for that municipality. Other authorities contend that this stand-by charge should not be borne entirely by the municipality, but that a portion should be charged against the water users themselves, as there must be water in the mains for the use of consumers as well as for fire protection.

A municipality should be charged for the actual amount of water it uses, no matter for what purpose. The water consumers should not be expected to pay for water used for city purposes. Such costs should be distributed over all the taxable property. In other words, the unit cost for the entire amount of water should be first established and then the amount used for fires and other public purposes should be metered or estimated and charged at the standard unit rate for that amount. A water-works is a public utility and should not be made to subsidize the tax-supported functions of municipal government.

The city of Cleveland has a uniform meter rate for its entire area and also uniform meter rates for each of the suburbs which it supplies. It does not make any reduced rates to large consumers. However, it is a well-known fact that increased consumption of any commodity at a given place will automatically reduce unit costs for the article delivered at that place. Therefore, in considering meter rates the most equitable method is a step-down rate for large usage. Such a rate tends to encourage the use of water for manufacturing or large commercial uses, but where used the charge to the domestic consumer has to be higher than a flat-rate scale. When a flat-rate schedule is used, the domestic consumer usually gets his product below actual cost, while the large user pays a large enough profit on the water he uses to make up the deficit. What plan to use if a step-down rate schedule is contemplated is a question that must depend upon special circumstances in each case. A rate schedule with many steps is not as easily figured as one with few steps. The billing is a little more complicated, but the more steps a step-down rate schedule has the more equitable it is to the various consumers as their consumption goes up.

The annual budget should be drafted by the chief financial officer of the water department in consultation with his division and subdivision heads and under the supervision of the chief executive of the city. It must be submitted to the legislative body (city council) for consideration and final action as to appropriations. Within the limits of the appropriation as a whole, the water-works manager should have authority to increase or decrease items as occasion requires during the year, as in the final analysis he is responsible for efficient operation of the works. Such authority is not usually granted, as city councils hesitate to place it in the hands of the executive.

The budget should contain a careful estimate of income and expense based upon the experience of the past several years. It should include:

1. A general statement of explanation showing: *(a)* sources of revenue, summarized; *(b)* nature of expenditures; *(c)* summary of expenditures under such headings as operation, maintenance, capital additions, sinking-fund requirements, etc.

2. A detailed statement of estimated revenues, including sale of water, service connections, sales deposits, special assessment funds and miscellaneous items.

3. A comparative budget and expenditure statement showing operation and maintenance, capital charges and other charges for several years past, together with the corresponding figures for the ensuing budget year.

4. Proposed expenditures in detail compared with the previous several years. This statement should be as detailed as the accounts themselves and the accounts should be in such detail as to make possible accurate budget control.

Unless a program for a given year is thus carefully laid out, a budget followed by an appropriation is likely to be nothing but a series of guesses rather than an accurate scientific instrument for the guidance of the management.

Plans for capital expenditures should always be made as carefully as an operating budget. A capital-expenditure budget should show in detail the exact nature of the proposed improvements, estimate of the costs and how they are to be financed—by bonds, special taxes, etc. There should be a program for a period of years. Ten-year programs are sometimes necessary to provide for water-works expansion. The preparation of such a long-term financial program is a matter of the greatest importance to a community.

BALDWIN WATER-FILTRATION PLANT, CLEVELAND, OHIO

Water-Supply Practice in Various Cities

Tank Faced With Stone and Brick

ATTRACTIVE appearance has been given a water tower recently constructed in a fine residential neighborhood in St. Paul, Minn., by inclosing the tank and pumping plant in a hexagonal tower of reinforced concrete faced with stone and brick. The tank, of 200,000-gal. capacity, is located immediately adjacent to an 18,000,000-gal. reservoir in Highland Park.

The tower is 127 ft. high to the top of the lantern, and contains four floors. The basement is devoted to

HIGHLAND PARK WATER TANK AT ST. PAUL, MINN.

the pumping equipment—two motor-driven centrifugal pumps of a capacity of 500 gal. per minute. The main floor is a large open room with a 17-ft. ceiling. The tank itself is 24 ft. in diameter and 60 ft. high, and is supported on a floor 25 ft. above the main floor. At a height of 92 ft. from the ground is the observation floor, which commands a view of the Mississippi gorge and valley of the Minnesota for miles. A spiral concrete stairway from the main floor to the observation floor is built into the space between the tank and the outside wall of the tower.

The lower 22 ft. of the tower is faced with Kasota stone blended with travertine, both from Minnesota quarries. Bedford stone, finished smooth, is used to face the top 23 ft., and the main body of the tower is cream brick, trimmed with Indiana and Oolitic limestone. On the pinnacle of the tower is a copper lantern with prism-glass panel inclosure, containing four 500-watt flasher lights. Lights located in the lions' mouths, just beneath the cornice, floodlight the upper 20 ft. of the tower.

The total cost of the tower was $71,500. The steel tank and pumping equipment could have been erected at a cost of about $20,000. An additional $20,000 would have been necessary to incase the tank in a plain way to house the pumping equipment with an inclosure for the attendant. The cost of the finer materials and architectural treatment, therefore, was $31,500.

The tower was designed and built under the supervision of John W. Kelsey, chief engineer, and Frank X. Lewes, city architect. Feyen & Selby, of St. Paul, were the general contractors.

Everett Averts Water Famine

By G. G. Paine

Water Department Engineer, Everett, Wash.

THE city of Everett, Wash., faced a serious water famine during the extreme cold weather of January, 1930, when that portion of its 28-in. supply pipe above ground gradually froze until the normal supply of 10,000,000 gal. per day (10 m.g.d.) had decreased to something less than 3 m.g.d. A catastrophe was averted by the quick action of city officials under the direction of C. F. Klapp, water superintendent.

On Wednesday, Jan. 15, realizing that it might be necessary to pump water from the Pilchuck River at a point where Everett's supply crosses that river near the city of Snohomish, there being no ice in the line between this point and Everett, Mr. Klapp made a hurried trip to Seattle, located the required pumping equipment and Thursday morning reported the situation to the city council, which, after a conference with a citizens' committee, authorized the installation of the emergency pumps.

Thursday noon the Puget Sound Bridge & Dredge Co. was instructed to install, with all possible speed, the first pumping unit consisting of two five-stage centrifugal pumps connected in series and direct-connected to one 650-hp. motor, pumping against a 450-ft. head. Water department crews began work immediately upon a foundation for the big pumps. This foundation was built up of heavy timbers placed in a pit 3 ft. deep and was ready for placing of pumps Friday morning, when the pumps were expected to arrive on trucks from Seattle. Due to the slippery condition of the roads and the ex-

EMERGENCY PUMPING STATION FOR EVERETT, WASH.

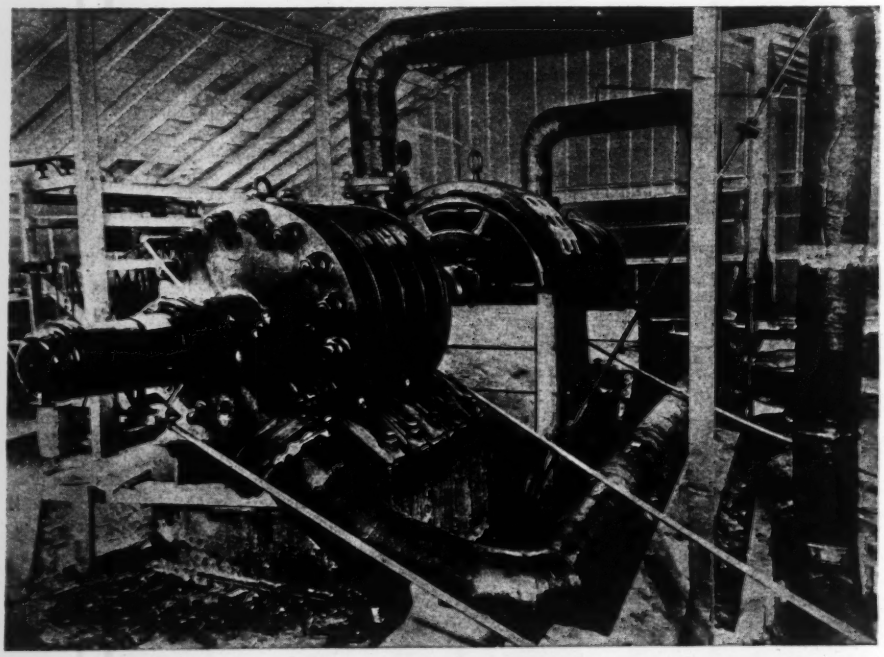
cessive weight of the outfit, the pumps did not arrive until late Friday night.

In the meantime work was rushed on the pipe layout necessary to connect the pumps to the 28-in. supply line through an 8-in. blowoff valve, the only possible connection that could be made without shutting down the already sadly diminished flow of water to Everett. The speed with which this piping layout was built up was due entirely to the use of oxyacetylene welding and to the fact that the water department had welders who were trained in this particular class of work. A 12x12x12-in. tee was made up of welded steel pipe with a 12-in. heavy-duty flanged valve on each end, anticipating the possible need of connections for two large pumping units with 12-in. discharge. The other outlet was reduced to 8 in. to give a Venturi action and flanged to fit the 8-in. blowoff on the 28-in. line. A 6-in. connection was made also in the side of this tee, or manifold, at the suggestion of C. E. Swanson, fire chief of Everett, who offered the services of two fire department pumps to help until the large pumps were hooked up. The three welders from the water department had this manifold ready for installation Saturday morning. In addition, by Saturday noon they had ready for complete installation the necessary elbows and angles made up of 12-in. steel pipe, which required approximately 100 cuts and 50 welds.

Saturday noon, the pumps having been bolted in place on the foundation, the water department welders, with the assistance of two outside welders, began welding together this system of elbows and angles which had been laid out on paper as accurately as possible to leave a minimum amount of welding to be done after the arrival of the pumps. All welds and connections were completed about 6 a.m. Sunday, and welders and other workers were ready for their first rest in more than 60 hours.

Of course, welding was not the only work that had been going on during this period. Linemen, electricians and carpenters were working night and day, each doing his very necessary part good-naturedly in spite of the long hours and extreme cold. Although the crews on the different parts of the work completed their jobs at practically the same time, and the pumps were started at approximately 6 a.m. Sunday, Jan. 19, due to the 12-in. suction line developing a faulty check valve which had to be removed and repaired, the actual delivery of water into Everett by pumps (other than the fire pumps, which had been running since Saturday morning) was delayed until Sunday evening, when there was a delivery at the rate of about 8 m.g.d. This amount was deemed inadequate owing to the extraordinarily high consumption caused by broken services and water running to keep from freezing, and so a second pumping unit was ordered which necessitated a duplication of nearly all the work required for the first unit, except that the 12-in. manifold connection was already in place for direct connection to the discharge pipe of this second unit and therefore the welding work was not as extensive. This unit was delivered from Portland, Ore., and put into operation Jan. 23, at which time the fire department pumps were removed and the remaining two units were delivering approximately 13 m.g.d. of water into the city and danger of a water famine was over.

Though the writer has stressed the important part welding had in this installation, due credit should be given to all of the men who willingly gave their services to avert what might have been a serious calamity to the city of Everett.



WELDED PIPE CONNECTIONS WITH FIVE-STAGE PUMPS, EVERETT, WASH.
Two pumps driven by one electric motor lift emergency water supply against 450-ft. head to supply main, upper exposed portion of which froze in cold January weather.

Water-Supply Practice

Pipe and Joints in Jerusalem

By Andrew Koch
City Engineer and Manager, Water-Supply Department, Jerusalem Municipality, Palestine

JERUSALEM has 150 kilometers, or 93 miles, of water mains in its new water-works system, laid from 1921 to date. Although our pipe is small (maximum 8 in.), it has several points of interest. It is of three kinds, each with a different type of joint; there are differences in coating; we carefully observe the behavior of our pipe as to breaks, corrosion, etc.; last but not least, the pipe has withstood two earthquakes during the nine years since the first of it was laid.

Most of our pipe, between 4 and 6 in. in diameter, is of wrought iron, with thread-and-socket joints, protected with (1) Dr. Angus Smith's coating, and (2) after laying, with three coats of red lead. No serious

Water-Supply Practice

defects have been found in this pipe and no corrosion except at one or two spots where sewage through leakage had access to the outside of the pipe.

Four years ago, at our Ain Farah works, we laid 6.2 miles of 8-in. wrought-iron pipe, with flexible (Victaulic) joints. Part of this pipe line is pressure main and part a distribution line. In the former the pressure rises to 20 kg. per square centimeter (284 lb. per square inch), and in the latter up to 6 kg. per square centimeter (25 lb. per square inch). The pressure main was laid mostly on hillsides, uncovered, while the distribution system is laid 80 cm. (31.5 in.) under the road surface. No defect, leakage, burst or corrosion has been experienced with this line, even during the earthquake, which at certain places moved the pressure main several inches from its original position.

We have also a short 8-in. line—1,000 m., or 3,280 ft.—of Mannesmann pipes with spigot-and-socket joints. We have not found this kind of joint—for our conditions—superior to the thread-and-socket joints and it has been much less satisfactory than the wrought-iron pipe with flexible joints.

Our experience with flexible joints, which can be completed in one-third the time required by the thread-and-socket joints, has led us to consider the advisability of adopting this system for all our future pipe. I should be gratified to learn of any of your readers who have had several years' experience with the behavior of such pipes, in the sizes from 4 to 18 in.

Salt Lake Rejects Wells for Reservoir

AFTER a thorough study of the problem of procuring an increased water supply, Salt Lake City, Utah, has decided in favor of an impounding reservoir in preference to the development of the groundwater supply of the region. An analysis of the proposals received for artesian wells on a deferred-payment plan, together with the results of a study of the legal questions involved, led to the conclusion that such a source of water was not sufficiently dependable to justify the investment necessary. Storage of surface water in the Big Cottonwood canyon has been decided upon, making necessary the construction of Argenta dam.

Alternative proposals were received for the development of artesian water supplies to furnish 15 m.g.d.; the second proposal included an alternate method of payment. These two bids were as follows:

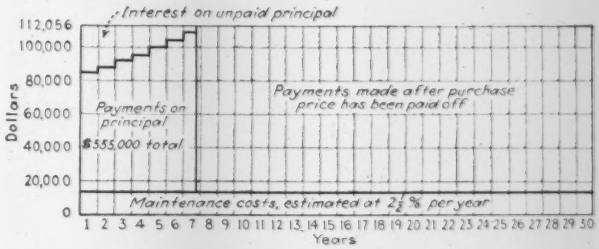
1. Direct purchase price of $553,500, payable $9,225 per month, plus 5 per cent interest on unpaid balance. The productivity of the wells was guaranteed for 5 years.
2. Purchase price of 3.7c. per gallon ($555,000 for 15 m.g.d.). Price decreases 3⅓ per cent ($18,500) per year if direct purchase is decided upon at a later date.
2. Alternate. Rental price $9,338 per month or $112,056 per year until plant is purchased outright on the gallon basis; or if such a purchase is not made for a period of 30 years, the system becomes the property of the city.

The five-year contract provided for a refund to the city of the sums paid if the supply should fail during the term of the contract, but the long-term contract contained no such provision. The maintenance of the plant during the guarantee period would be assumed by the contractor. Power and operating costs would be paid by the city. Under the rental plan, maintenance expenses would be borne by the contractor until the plant was purchased by the city.

The costs of purchasing or renting the system under the terms of the second proposal were analyzed for the purpose of explaining the apparent inconsistency between a rental price of $112,056 per year for 30 years and a direct purchase price of $555,000. In return for this rent, the city would receive:

1. Maintenance of the system, estimated by the contractor to cost 2½ per cent yearly of the original purchase price	$13,875
2. Reduction of purchase price	18,500
3. Interest on unpaid balance at 5 per cent	27,750
	$60,125

Thus there appeared to be a discrepancy of nearly $52,000 between the amount the city would be obliged to pay as rent and the value it would receive in return during the first year. And further, as the interest on the unpaid balance would decrease in subsequent years, this discrepancy would grow larger as time went on. It


Interest on unpaid principal
112,056
100,000
80,000
60,000
40,000
20,000
0
Dollars
Payments on principal $555,000 total
Payments made after purchase price has been paid off
Maintenance costs, estimated at 2½% per year
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Years

ANALYSIS SHOWS WELL RENTAL PAYMENTS WOULD CONTINUE AFTER TOTAL COST WAS PAID

became apparent that the alternate plans included in this proposal were not equal in value, and that it would be much cheaper for the city to purchase the system outright as soon as possible.

Under the terms of the first proposal the city would pay off the entire purchase price of $553,500 in five years at the rate of $110,700 per year, plus interest on the unpaid balance at 5 per cent, or at an initial yearly cost of $132,840. The difference in yearly charges under the two plans was seen to be insufficient to account for the much longer term of the contract under the second proposal.

To determine the reason for the inclusion of the $52,000 extra yearly charge in the rental of the system, computations were made based upon the assumption that the payment on principal under the rental plan included all amounts over the costs of interest and maintenance. The accompanying diagram shows graphically the results of these computations. It was seen that under these assumptions the purchase price of $555,000 would in reality be paid off in 6⅔ years in spite of the fact that the contract called for payments to continue for 30 years. The conclusion drawn was that the $52,000 charge was in the nature of a mortality cost and represented the difference between $18,500 and one year's share of the price of the installation based on its estimated production life.

It was evident from this analysis that the long-term contract did not have the nature of a 30-year guarantee and that the five years guaranteed in the first proposal was the greatest length of time the productivity of the wells could be depended upon. This conclusion was substantiated by the results of a survey of existing artesian

wells in the field proposed to be tapped. The static head on practically all the wells was found to be decreasing because of the fact that the yearly recharge of the artesian field was exceeded by the rate at which water was being withdrawn.

Further objections to the well contracts, based upon legal considerations, were presented by the city attorney. It was pointed out that in view of the legal status of underground water in the State of Utah, Salt Lake City would in all probability be enjoined from using water developed by sinking artesian wells, if such use interfered with the correlative rights of other landowners in the artesian district, or interfered with the prior rights established by other persons who were using the water after it had reached the surface. The well contracts were such as to offer no redress to the city in case of such an injunction, but required the city to continue in its payments even though it became impossible to use the water.

The project finally recommended is the construction of the Argenta dam in Big Cottonwood canyon, including an impounding reservoir of 12,000-acre-feet capacity. The total cost of the project is estimated to be $2,286,000. The first vote on the bond issue, however, on May 6, was unfavorable to the extent of 4½ to 1. The engineering analysis and the recommendations for the Argenta dam project were made by Harry C. Jessen, city engineer, Salt Lake City, Utah.

East Bay System Completed

By F. W. Hanna

Chief Engineer and General Manager, East Bay Municipal Utility District

SINCE the East Bay Municipal Utility District began active work in 1925 on the Mokelumne project to provide a mountain water supply for the nine cities on the east side of San Francisco Bay the main storage dam has been completed, the aqueduct built and the privately owned distribution system purchased. Following the formation of the district in 1923, the first money for investigations became available in 1924. After four months' intensive field and office study the development of the Mokelumne River as a future source of supply was selected and the choice approved by a consulting board. In November of that year a bond election provided $39,000,000 for the construction of storage works and aqueduct. After clearing up the major legal difficulties, active building was started in the fall of 1925. Completion of the project, to the point of delivering water to the district in the summer of 1929, enabled the replenishing of the local supply reservoirs just in time to avoid a serious water famine.

The main storage of 204,000 acre-ft. is provided by the Pardee dam, a curved gravity structure 357 ft. high above the foundation, containing 615,000 cu.yd. of concrete. Two separate spillway structures containing an additional 43,000 cu.yd. of concrete have a combined discharge capacity of 141,000 sec.-ft. The outlet tower, which is 193 ft. high, contains fifteen gates in groups of three; each group can discharge 200 m.g.d. into the aqueduct.

The 95-mile aqueduct includes four tunnels with a combined length of 9.3 miles, a reinforced-concrete section 3.5 miles long and a steel pipe line 65 in. in diameter for the remainder of the distance. With the present pumping plants, this conduit has a capacity of 60 m.g.d.

However, the tunnels and concrete section have been designed for an ultimate capacity of 200 m.g.d. and, when necessary, pipe lines will be added to make this flow available.

Since the bringing in of the Mokelumne supply, the quality of the water served to the district has improved consistently and, in addition, the amount of storage behind Pardee dam eliminates any possibility of future water shortage in the district.

Colorado Supply for Los Angeles

THE proposed aqueduct project to bring a domestic water supply from the Colorado River to the cities near the coast of Southern California has been advanced materially as the result of agreements reached in recent months by conflicting interests within California regarding a division of water and an allocation of power. These agreements, and resulting contracts executed with the federal government in compliance with the Boulder Canyon project act, represent the basis of the request of President Hoover and Secretary Wilbur for a congressional appropriation of $10,660,000 with which to begin work at Boulder Canyon dam site.

The aqueduct, which is a distinctly separate enterprise from the Boulder Canyon dam, is to be constructed by the Metropolitan Water District of Southern California, comprising at present eleven cities: Los Angeles, San Marino, Pasadena, Glendale, Burbank, Beverly Hills, Santa Monica, Anaheim, Santa Ana, San Bernardino and Colton. The Boulder Canyon dam and the aqueduct projects are related in that regulation of the river flow is essential for the proposed diversion of 1,500 sec.ft., or approximately 1,100,000 acre-ft., to the cities near the coast. In view of the identical elevations of several of the possible diversion points with areas where the water is to be used 300 miles or more away, and the several mountain ranges intervening, it is expected that high pumping lifts aggregating 1,600 to 1,800 ft. will be found economically justifiable.

Preliminary surveys and location studies on the aqueduct were begun by the city of Los Angeles in 1925. Various locations were investigated, ranging from a gravity route diverting from a high dam at Bridge Canyon, 150 miles upstream from Boulder Canyon, to a diversion at Picacho, 30 miles north of Yuma. Direction of this preliminary work was transferred to the Metropolitan Water District in the summer of 1929 and full financial responsibility for the continuance of the work was assumed by the district on May 1, 1930.

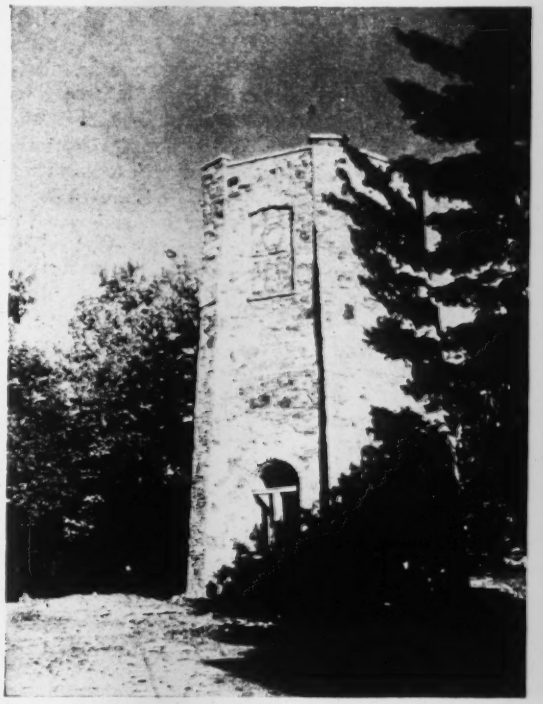
In September, 1929, a board of engineers composed of Thaddeus Merriman, of New York, Richard Lyman, of Salt Lake City, and A. J. Wiley, of Boise, was retained by the Metropolitan Water District to recommend the most advantageous and economical aqueduct route. This board recommended that future investigations be concentrated upon four routes to have diversion points respectively at Boulder Canyon, Bulls Head (40 miles above Needles), Parker and Picacho. An abstract of this report was published in *Engineering News-Record*, Jan. 9, 1930, p. 59. Final choice of the aqueduct route probably will be made this year.

Water-Supply Practice

The right of the district to divert water from the Colorado River is based upon a succession of agreements as to allocations. The Santa Fe compact assigns to the three lower states of Arizona, Nevada and California within the Colorado River basin, the right to appropriate 8,500,000 acre-ft. annually and one-half of the surplus waters in the river. The Boulder Canyon project act allocated to California 4,400,000 acre-ft. annually plus one-half of the surplus available to the lower states. Recently an agreement was reached between the appropriators of water for agricultural uses of the Blythe and Imperial Valley regions and the Metropolitan Water District on the division of California's share of the waters of the Colorado.

On April 26, 1930, contracts for the entire power production, estimated at 650,000 hp. (firm power), from the Boulder Canyon development, were signed by the Metropolitan Water District, the city of Los Angeles and the Southern California Edison Co. *(Engineering News-Record*, May 1, 1930, p. 737). These contracts provide revenue to the federal government which will meet interest and amortization requirements over a 50-year period.

The engineering personnel of the Metropolitan Water District includes F. E. Weymouth, chief engineer; Julian Hinds, designing engineer; James Munn, chief of construction; and J. B. Bond, chief field engineer.



STONE MASONRY TOWER INCLOSING WATER TANK

Stone masonry water tower at Banner Elk, N. C., part of water supply for Lees-McRae College. Water passes through a pressure filter, is chlorinated, and stored in a 20,000-gal. cypress tank in the top of the masonry tower. The water system was designed by Prof. J. A. Switzer, of the University of Tennessee. D. R. Beeson was the architect for the tower.

Piecework Pay for Meter Readers

By E. R. Holloway

Superintendent, Water Department, Flint, Mich.

FOR reading water meters and billing customers, Flint, Mich., is divided into three sections and all accounts which average under $10 per month are read and billed quarterly. Those averaging over $10 per month are put in a special ledger and billed monthly. The routes of the readers are so arranged that the reading and billing are continuous and the work is equally distributed throughout the month. Two employees read all the meters which are billed on the quarterly basis, about 30,400 in number. They are paid for these readings at the rate of $3 per 100. It might at first appear that because the work is put on a production basis, the readers might be inclined to hurry, resulting in inaccurate readings. This is not true, inasmuch as any readings that are handed in and are found later to be incorrect are deducted from the reader's pay check. This penalty makes him cautious in his work. It also has the advantage that the fast, hardworking meter reader receives compensation in proportion to his efforts, while those that might be inclined to be careless and slow automatically reduce their income accordingly.

When these readers are sent out on their routes the slips which they use show merely the name and address of the consumer, and location, size, make and number of the meter. The omission of the previous reading compels them actually to view the meter before a reading can be handed in. The slips are arranged so that the odd numbers on the street come in numerical order and the even numbers the same way but in reverse rotation. This enables the reader to go up one side of the street and back on the next, having his slips come in the same rotation as the house numbers.

At night the readings are handed in to the billing department, where they are posted in the books and carefully compared with previous readings. Any abnormal variation is checked by an extra reader, who is used as a follow-up man to get any readings where the consumers were not at home when the regular reader called. This man also reads meters for which monthly bills are sent and makes other special investigations.

Pasadena Water Department Policy

A BASE rate for domestic use of water in Pasadena, Calif., is 13c. per 100 cu.ft., and for irrigation and municipal use it is 6c. A minimum monthly rate is charged, varying with the size of meter, as follows: For a $\frac{5}{8}$-in. meter 500 cu.ft. or less costs $1. The same amount for $\frac{3}{4}$- and 1-in. meters costs $1.15 and $1.40 respectively. Through $1\frac{1}{2}$-in. meters the first 700 cu.ft. costs $2.10; through 2-in. meters the first 1,000 cu.ft. costs $2.85; through 3-in. meters the first 1,500 cu.ft. costs $6.60, and through a 4-in. meter the first 2,000 cu.ft. costs $8.10. Irrigation minimum rates in force

are slightly less than half the above outlined minimum domestic rates.

Installation of new service connections are charged for at the rate of $15 for ¾-in., $20 for 1-in., $25 for 1½-in. and $45 for 2-in. connections. Meter installations other than for irrigation are put in free. Where services are forced in ahead of street work 10 per cent is added.

Since its organization in 1912 the department has not received any money from any source other than its normal revenue. Expenses for operation, maintenance, depreciation, bond interest and redemption and much construction have all been cared for on this basis. Water for fires and flushing sewers is free to the city, but the water department officials do not defend the practice of furnishing free water. The water department pays for every service received from other city departments, including rental of space occupied in the city hall and other buildings, light, power, heat, janitor service and portions of salaries of city attorney, controller and other officers rendering any ordinary or special service. The earnings for the year 1929, as shown in the annual report of S. B. Morris, general manager and chief engineer, are 7.43 per cent on the depreciated present value of the combined capital and current assets.

Costs of a Water Distribution System

By Max Van de Gren
Village Manager and Engineer, Roseville, Mich.

UNIT costs of a water-distribution system built by the village of Roseville, Mich., in 1928-1929, are shown by the accompanying table. They cover nearly 54 miles of

Water-Supply Practice

24- to 6-in. pipe, with valves and hydrants on most of it, the 24-in. pipe being a feed main from the Detroit waterworks, continued after passing through East Detroit.

Filtered water is supplied and the distribution system is operated by the city of Detroit under its regular terms to outside communities. All plans are to be approved by the Detroit water board. Sizes and location of pipe are to follow the master plan of the Detroit metropolitan area. Valves and fire hydrants are to be of Detroit standard. The village is to provide foundry inspection of pipe and to pay Detroit for inspection of pipe laying at 3½c. per foot. All services are to be metered. Title to all mains larger than 8 in. is to be given to Detroit. The village is to form a water board to operate the works. Detroit is to be paid for all water it supplies at double the meter rates charged in Detroit, the entire supply, in the case of Roseville, passing through a single meter at present.

A contract including all these conditions was approved by a popular vote of the village, as was also a $350,000 construction bond issue. The amount named was based on the assumption that a part of the cost of the works would be assessed upon the property benefited at the rate of 87½c. per front foot. Later the assessment was fixed at 40c., and $450,000 of additional bonds were authorized.

The plans and specifications for the Roseville distribution system were drawn and construction was supervised by the village engineering department, under direction of the writer. R. M. Freeman was assistant engineer.

COST OF WATER WORKS DISTRIBUTION SYSTEM OF ROSEVILLE, MICH., BUILT IN 1928–29

Year	Kind	Class	Size, In.	Length, Ft.	Valves		6 In. Fire Hydrants*		Total Amt. Contract	Cost†				Pipe Size (In.)				Inspection	
														Per Cent Footage					
					No.	Cost	No.	Cost		Av. Pipe per Ft.	H'dts. per Ft.	Valves per Ft.	Fdry. Insp.	6 In.	8 In.	12 In.	24 In.	Det. Water Bo. @3½c. per Ft.	Foundry
1928	Sand cast.	C	24	14,425	7	$7,000													
		C	12	249	7	1,400													
		C	8	1,748	22	3,080													
		B	6	444															
		B		16,866	36	$11,480	13	$1,625	$141,910	$8.41	$0.096	$0.068		2.6	10.4	1.5	85.5	590	
1928	Sand cast.	B	8	14,988	24	$3,480													
		B	6	6,714	25	3,125													
				21,702	49	$6,605	41	5,125	52,991	2.44	0.236	0.304	0.02	30.9	69.1			760	754
1929	Spun	150‡	12	6,873	6	$735	160	18,400											
		150	8	52,242	86	7,482	4	340											
		150	6	29,593	127	9,652													
				88,708	219	$17,869		$18,740	156,236	1.76	0.211	0.201		33.3	58.9	7.8		3,105	
1929	Spun	150	8	20,908	22	$1,980	132	$15,180											
		150	6	62,303	69	5,520	15	975											
				83,211	91	$7,500		$16,155	110,068	1.32	0.194	0.09		74.9	25.1			2,912	
1929	Green sand mold.	150	8	21,296	22	$1,674													
		150	6	51,069	73	6,216													
				72,365	95	$7,890	118	14,750	97,993	1.35	0.204	0.109	0.012	29.4	70.6			2,533	2,961
	Two years' work			282,852	490	$51,344	483	56,395	560,513	1.98	0.199			53.1	39.3	2.5	5.1	9,900	3,715
	Excluding 24-in. feeder main		12	7,122															
			8	111,182															
			6	150,123	454	$39,864	470	54,770	418,603	1.57	0.206	0.15	0.013	56.4	41.8	1.8			
				265,986															

The soil in which the pipe is laid varied from blue clay to water-bearing sand. All excavation by either pull-type of trenching shovels or else by trenching machines. The 24-in. main was laid to grade with an average cover of 6 ft. The smaller pipe had a minimum cover of 6 ft. They were laid on the south and west sides of the streets, 10 ft. from the property line, to bring them between curb and sidewalks. Larger mains, on wider streets, were laid to conform, so far as possible to the superhighway standards of the Detroit metropolitan area. In many cases this required running through fields, across lawns and under buildings. Lead joints used throughout.

*All valves and hydrants Detroit standard. †Does not include foundry inspection at village expense or Detroit pipelaying inspection given in last two columns; nor village engineering and inspection, which cost about 2 per cent of total outlay. ‡Pounds pressure.

Hydraulic-Fill Dam of Fine Volcanic Ash Fails Disastrously

Over Half of Placed Fill of Alexander Dam on the Hawaiian Island of Kauai Sloughs Out With Embankment Nearly 80 Per Cent Completed—Analyses of Materials, Description of Failure and Interpretation of Causes Compiled from Information Coming Directly From the Engineer

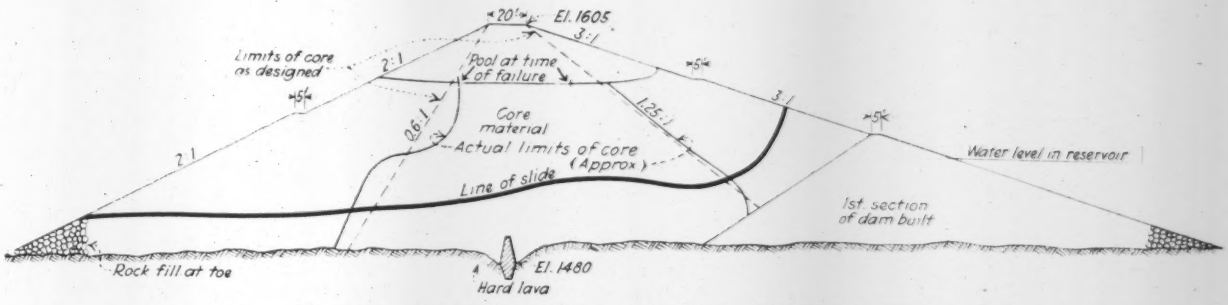


FIG. 1—SECTION SHOWING DESIGN OF DAM AND LINE OF MAXIMUM SLIDE
At time of failure the reservoir level was about 1,535 and the core pool level 1,574.5.

THE MOST DISASTROUS failure of a hydraulic-fill structure that has occurred in recent years was announced in the news published in *Engineering News-Record*, April 17, 1930, p. 665, that the Alexander dam on the Hawaiian Island of Kauai had gone out during construction. The design and general methods of constructing this dam, as they were seen six months ago, when the work had just been well started, were described in *Engineering News-Record* of April 26, 1930, p. 703. From a report made to the editors of this journal by Joel B. Cox, chief engineer of the dam, it is now possible to give a circumstantial account of failure, the studies undertaken following the accident, and the conclusions that seem reasonable in respect to the causes of the failure. The dam was a trapezoidal embankment 125 ft. high and 620 ft. long on the crest. About 453,000 cu.yd., bringing the fill to a height of 95 ft., had been placed when failure occurred. The material displaced by the slide was 257,000 cu.yd. —EDITOR.

THE Alexander dam is being built to create a reservoir which will be an important addition to the water-supply system of the McBryde Sugar Co., Ltd., operating a sugar plantation on the south shore of Kauai, the northernmost island of the Hawaiian group. The structure occupies a natural contraction in the valley. The north abutment ridge fits almost perfectly the adopted dam section, but this ridge bends away so rapidly that any material increase of section is an economic impossibility.

The reservoir to be created has a capacity of 806,000,000 gal. (2,300 acre-ft.), which appears small compared with the 575,000 cu.yd. of material in the dam. However, this ratio is better than that of the average storage site in the islands, where 1,000 cu.yd. of earth usually is required to provide a million gallons of storage. This limited storage capacity does, however, strictly limit the allowable expenditure for the dam.

To expedite the utilization of water for irrigation and to provide power for construction, the upstream heel of the dam was built first, to height of 50 ft. Construction of this initial section began in August, 1928, and was completed in January, 1929. Sluicing on the main dam began in May, 1929.

The materials available and their probable action in a hydraulic-fill structure are the points of chief engineering interest. The materials for the fill are found in the two ridges forming the dam abutments, and consist of a heterogeneous mass of very thoroughly decomposed volcanic material. In the south abutment the ground originally was ash or clinker from a cone in the near vicinity, and indications point to some evidence of general and extensive fumarole action in its early geologic history. In the north abutment there is some vesicular lava, also some that is almost completely decomposed. The raw material is therefore (with the exception of residual boulders from the lava in the north ridge) a heavy earth, claylike in character and variable in color, with red predominating. There are no definite hard grains of any considerable size, and agitation in water will reduce the grain size to any desired degree. The mechanical analysis of this material is therefore entirely a function of the degree of preparation by shaking or stirring. The larger lumps are utilized to form the upstream and downstream sections of the hydraulic-fill structure. The fine grains and colloidal material form the core.

Materials Carefully Studied

Starting with general knowledge of the available material, which obviously would provide an overabundance of fines for the core and a dearth of heavy coarse material for the slopes, the fundamental design and construction problem was to predict the internal pressures and rate of consolidation in the core, and the weight and coefficient of friction in the side sections, so that these factors could be properly balanced to provide a safe and economic structure.

To follow precedent and restrict the width of the core to slopes of 2 on 1 would have presented two major difficulties in addition to the extra cost of moving the rejected material. The first would be the expense and difficulty of handling the wasted material because, for various reasons, it was extremely undesirable to turn large quantities of colloidal mud into the gulch below the dam. Second, the wastage of the water to carry this mud would be great enough (with the restricted water supply) to delay greatly the completion of the dam.

In spite of the apparent difficulties involved in using the type of coarse material available for the outer sections of a high dam, previous experience on a number of dams up to 70 ft. in height built of similar material, together with the high shearing coefficients shown by tests, led the engineers to conclude that the major problem would be the proper consolidation of the core, and research was centered on this problem. Through the co-operation of the Hawaiian Sugar Planters' Association, the services of Dr. F. E. Hance, physical chemist at the experiment station in Honolulu, were made available and an intensive study of the available material was undertaken.

The material which would compose the outer slope sections was first subjected to tests to show its coefficient of friction or shearing resistance (under the range of moisture conditions possible in an open testing machine), together with its weight and mechanical analysis. Following this, the core material was studied intensively in several ways. Its compressibility and permeability were determined by the methods of Dr. Charles Terzaghi. Study was made of the results which were produced by changing the chemical reaction in the material by treatment with various bases and acids. This work and the principle of treating the colloidal condition of the material were outlined by Dr. Hance in *Engineering News-Record*, Oct. 3, 1929, p. 542. Mechanical analysis was made by noting the settlement of a hydrometer in a suspension of the material, after proper peptization had eliminated flocculation effects; this study used the method originally devised by George Bouyoucos. The phenomena of friction, cohesion and ratio of lateral to direct pressure were carefully studied.

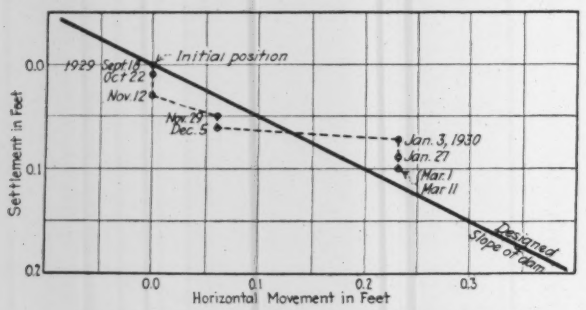


FIG. 2—RECORD OF MOVEMENT OF THE REFERENCE MARK NEAREST POINT OF SLIDE

The most significant development of this investigation was the chemical treatment used to increase the density and impermeability of the core material placed next to the concrete cutoff wall. Predetermined amounts of soda ash were added to this mud in sufficient quantity to deflocculate the material. This treatment was used only on the core adjacent to the cutoff wall for a depth of 8 ft. and was not applied to the main body of the core material.

These laboratory studies were supplemented by attempts at direct measurements of pressures in the core by Goldbeck pressure cells and by drill samples of core recovered at various depths. A method was devised to apply the theory of consolidation of clay, as derived by Dr. Terzaghi, to a hydraulic-fill core in process of construction, and its results were compared with the field measurements.

The drill samples gave some evidence of conditions within the coarser material in the slopes, but the main reliance as to stability of these sections was placed in friction tests and in careful and systematic measurements of reference points on the face of the dam. A study of the Calaveras dam slip led those in charge to believe that a bank failure due to core pressure would give some warning by a preliminary outward movement of such reference marks. The recorded motion of the reference mark nearest the initial break is given in Fig. 2. It will be noticed that there had been no outward movement for 2½ months up to and including the day before the accident, and that the total movement had been only 0.23 ft.

How the Slide Occurred and Acted

The slip on March 26 occurred suddenly, without preliminary warning of any kind. The following account of R. J. Williams, the engineer in charge of the work at the dam at the time, is the best available description:

> At 3:45 p.m., March 26, 1930, just after the men had finished building the downstream dike and had left the dam, a major slide occurred. I had just completed a trip across the downstream beach, where sluicing was going on approximately 80 ft. from the south abutment. Going to the top of the bank, I saw Nakao talking with his son in the center of the dam on the upstream beach, and as I wished to give him some instructions regarding the night's work, I met him at the junction of the embankment and the top of the dam (El. 1,575 ft.). While indicating some detail by tracing a design of it in the ground, I saw him give a violent start. I was facing northeast (slightly upstream), and upon turning my head saw a section of the downstream flume, probably that beginning about 150 ft. from the north abutment, sink slowly down out of sight. There appeared to be a pause, after which the core pool also went down and out. By this time I was running to the top of the hill, a distance of approximately 100 ft. I have a vague impression that the core, as it neared the falls, was intact to a certain degree—somewhat like a large ball, but with several large cracks in the top.
>
> The overhanging upstream beach with its flume also went down, the upper portion going down the gulch, while that underlying remained in the dam. Approximately 60,000,000 gal. of water was impounded at the time. The water elevation of the core pool, gaged ten minutes before the break, was 1,574.5.
>
> I estimate the time of the entire occurrence, from the time the downstream flume was first noticed by me as sinking, to the large slough of the overhanging upstream beach, at less than 30 seconds.

A report of another eyewitness, who saw the initial failure of the downstream bank, states that it bulged out immediately over the rockfill at the toe and moved outward over a comparatively narrow front, with a gush of liquid mud. It is to be noted that this gush of liquid material seems to have occurred an appreciable time before any movement was observable in the core pool, and that the latter remained intact until it was released by the sinking of its downstream bank.

A second significant fact is that this first movement was not only comparatively narrow but at a large angle with the normal to the dam axis. This was evident from the

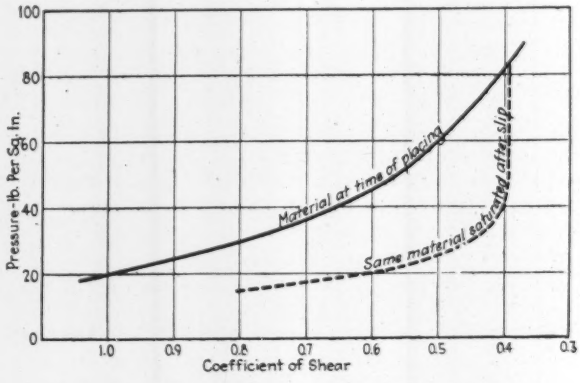


FIG. 3—RESULTS OF SHEAR TESTS ON MATERIAL FORMING THE SIDE SECTIONS

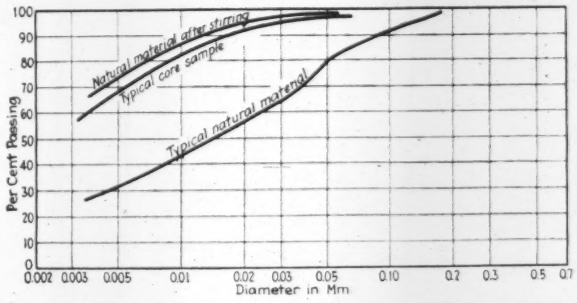


FIG. 4—MECHANICAL ANALYSIS OF MATERIAL USED IN DAM

distribution of débris as well as from the accounts of eyewitnesses. A third observation that has been made and carefully checked is that the fluid mud which accompanied the initial movement and which splashed up the valley wall opposite is not core material and can only either have originated in the transition zone or have been created from a portion of the beach during motion under heavy pressure when saturated. The chemically treated material near the cutoff wall did not move during the slip and, according to reports, had no connection with the causes of the collapse.

The dam cross-section at the point of maximum failure is shown in Fig. 1. The core on each side of the gap remained in place at a comparatively steep angle, and it still remains against both valley walls below the limits of the pool itself. Although the north end of the downstream bank collapsed in the last movement of the dam, it hung together through a considerable period and was not carried out by the flowing material. The south end of the downstream bank is intact and firm with a considerable portion of core behind it.

After the accident it was learned that men at work on the dam had noticed a cessation of drainage through the bank in the vicinity of the initial break at least ten days before the failure. Up to this time, the drainage had appeared free and well distributed. Unfortunately no precise measurements are available.

Following the slump, large samples were taken of the materials still in place and from the dam débris, and are now being subjected to an important series of tests. The most interesting of those already completed are shown in Figs. 3 and 4. The testing machine has been rebuilt since the accident to make it possible to obtain shearing coefficients under complete saturation. In all the tests the high importance of cohesion as opposed to true friction is apparent.

Collapse Caused by Obstructed Drainage

The following is an interpretation of the accident by the engineer in charge: The core was developing outward pressures probably well within those derived by computation and was consolidating satisfactorily. At the same time the bank was developing the required resistance as long as it drained properly. In a portion of the bank a critical pressure had been reached under which the permeability rather suddenly was reduced, due to the crushing of the grains which had limited structural strength, and the consequent filling up of the paths of percolation. This resulted in the accumulation of a body of water under considerable head in the transition zone and a portion of the shell next the core. When the lubricating effect and the reduction in effective friction due to uplift had reached a critical point, this section of the bank suddenly failed in a typical land-slip action, sliding on the surface of the relatively firm core. When this had dropped sufficiently to release the core pool, the liquid core and a portion of the plastic core followed, with an accompanying collapse of those portions of the upstream beach which were left overhanging.

Losses and Reconstruction Plans

The accident resulted in the loss of six lives. Due to the cheapness of the method of placing fill, the actual loss involved is comparatively small. Present estimates place it at well under $80,000. Of greater importance to the plantation is the loss of time in placing the reservoir in full operation.

It has been decided to reconstruct the damaged portion as rapidly as possible. While full plans for reconstruction have not been completed, they will probably include (1) the maximum feasible reduction in core width; (2) artificial drainage of banks; (3) use of all the boulders and other rock obtainable in larger rockfill toes; (4) a careful selection of the available material, rendered comparatively easy by the large borrowpit faces exposed by the previous sluicing operation.

The Alexander dam is being constructed by the McBryde Sugar Co., Ltd., whose agent is Alexander & Baldwin, Ltd., of Honolulu and San Francisco. Joel B. Cox is the engineer in charge.

FIG. 5—LOOKING TOWARD SOUTH ABUTMENT OF ALEXANDER DAM AFTER SLUMP OF 257,000 CU.YD.

News of the Week

Bill Establishing Hydraulic Laboratory Signed by President

$350,000 Appropriated for Building and Equipment — Bureau of Standards to Have Charge

AFTER seven years of effort by the engineering profession, the bill providing for a national hydraulic research laboratory in the Bureau of Standards, Washington, D. C., has become a law, having been signed by President Hoover on May 14. The bill as passed is as follows:

An act authorizing the establishment of a national hydraulic laboratory in the Bureau of Standards of the Department of Commerce and the construction of a building therefor.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That there is hereby authorized to be established in the Bureau of Standards of the Department of Commerce a national hydraulic laboratory for the determination of fundamental data useful in hydraulic research and engineering, including laboratory research relating to the behavior and control of river and harbor waters, the study of hydraulic structures and water flow, and the development and testing of hydraulic instruments and accessories. Provided, That no test, study or other work on a problem or problems connected with a project the prosecution of which is under the jurisdiction of any department or independent agency of the government shall be undertaken in the laboratory herein authorized until a written request to do such work is submitted to the director of the Bureau of Standards by the head of the department or independent agency charged with the execution of such project. And provided further, That any state or political subdivision thereof may obtain a test, study or other work on a problem connected with a project the prosecution of which is under the jurisdiction of such state or political subdivision thereof.

Sec. 2. There is hereby authorized to be appropriated, out of any money in the Treasury not otherwise appropriated, not to exceed $350,000, to be expended by the secretary of commerce for the construction and installation upon the present site of the Bureau of Standards in the District of Columbia of a suitable hydraulic laboratory building and such equipment, utilities and appurtenances thereto as may be necessary.

Establishment of a national hydraulic research laboratory was originally proposed by John R. Freeman in a presidential address before the American Society of Civil Engineers. Legislation to authorize its construction was first introduced before Congress in September, 1922, by Senator Ransdell, of Louisiana. Although a number of hearings were held upon the measure, and it carried the indorsement of the American Engineering Council from the start, it failed of passage, not only by the 67th Congress but also during each Congress since that time. Reintroduced before the present session for the fifth time, the bill was regarded more favorably, especially after its indorsement by Major-Gen. Lytle Brown, Chief of Engineers. Final agreement on the bill, with amendments, was reached by the two houses on May 8, and on May 14 President Hoover gave his approval.

Connecticut River Diversion Approved by Special Master

The proposed diversion by the Massachusetts Metropolitan Water District of water from the Ware and Swift rivers, tributaries of the Connecticut River, for the use of Boston and vicinity has been upheld by Charles W. Bunn, special master appointed by the U. S. Supreme Court to hear Connecticut's plea for an injunction against the diversion. Only inconsequential damage to navigation, agriculture and the sanitary condition of the Connecticut River will result from the proposed diversion, according to the report.

Salt Lake City Defeats Water Bond Issue 4½ to 1

By a vote 1,754 in favor to 7,970 against, more than 4½ to 1, the citizens of Salt Lake City have rejected a proposed $3,000,000 water bond issue. The one-sided vote was a decisive expression of lack of confidence in the city administration's plan to build a dam and reservoir at Argenta in Big Cottonwood Canyon and otherwise extend the city's water supply system. The vote was the heaviest ever recorded in a bond election in the city's history, and was the more remarkable because there was a continuous downpour of rain during the voting hours.

Tallest Towers to Carry Power Over Mississippi

The federal government recently granted the Baton Rouge Electric Co. a permit covering the erection of a 66-kw. transmission line over the Mississippi River at Baton Rouge, La., on two 425-ft. towers, as a part of a line now nearing completion. The towers, according to government representatives, are the tallest river crossing towers in this country.

License for First Flathead Power Site Given by Commission

Rocky Mountain Power Co. Authorized to Start Development—Case May Be Carried to Courts

STUDIED attacks from various angles have been directed against the Flathead project of the Rocky Mountain Power Co. for the past nine months. Despite all this agitation, the Federal Power Commission on May 19 authorized the issuance of a license to the Rocky Mountain company for site No. 1 on the Flathead River. Four other sites of much less importance are left open for future determination. Before final issuance the license must be approved by the legal division of the Interior Department, but since it was drawn very carefully under competent legal guidance, that qualification is regarded as a perfunctory one.

Walter H. Wheeler, of Minneapolis, who filed a conflicting application, served notice on the commission that he would exercise the right of appeal and demand a review by the Cabinet members composing the power commission. Since the members of the commission voted unanimously to authorize the license, it is assumed that their position will not be changed by any hearing that may be granted Mr. Wheeler, who already has been heard at great length in defense of his project. In this event, Mr. Wheeler states, he expects to carry the case to the courts. Secretary Wilbur in announcing the results of the meeting said: "The accepted plan gives a sure rental to the Indians rather than to involve them in a speculative enterprise such as the bringing in of possible new industries into an area distant from normal markets. The present plan can be carried out promptly, since the Rocky Mountain Power Co. is ready to begin operations at once."

In its original application the power company offered to pay $1 per horsepower to the Indians, whose reservation includes a portion of the Flathead Lake and the actual power site. After careful study of the matter, however, the commission required a flat rental which, over the twenty-year period set up in the license, averages $1.85 per horsepower. While the project is under construction the Indians are to receive $1,000 per month. Construction is expected to take three years. Five years is then given to build up the load, during which time the rental on a progressive scale works up to $125,000. This is stepped up until the annual rental reaches a maximum of $175,000. At the end of twenty years there is to be a restudy of the rental and provision made

VICKSBURG BRIDGE FORMALLY OPENED TO TRAFFIC

Although it has actually been in use for some time, ceremonies incident to the formal opening of the new combined railroad and highway bridge over the Mississippi River at Vicksburg, Miss., were not held until May 20. The structure has a cantilever channel span of 825 ft., with 420-ft. anchor arms. The east approach consists of a 260-ft. viaduct and a 181-ft. deck truss; the west approach of a steel viaduct 4,112 ft. long and three through-truss spans. The deck carries a single railroad track and an 18-ft. roadway. Harrington, Howard & Ash, Kansas City, designed the structure for the Vicksburg Bridge & Terminal Co. The contractors were: substructure, U.G.I. Contracting Co.; main spans, American Bridge Co.; approaches, Virginia Bridge & Iron Co.

for a readjustment. The total rental for site No. 1 during the twenty years will be $2,845,000.

In addition, provision is made for the interests of the white settlers on the reclamation project. The license provides that power is to be furnished for pumping at a rate of 1 mill per kilowatt-hour for the first 10,000 hp. That power is reserved exclusively for pumping purposes. An additional 5,000 hp. is to be added, however, at the rate of 2½ mills, which may be resold for the account of the reclamation project. The power company also will pay the federal government $101,000 by way of reimbursement for the work already done on the Newell tunnel, through which the river will be diverted during the construction of the dam.

California Acts to Reduce Grade-Crossing Accidents

In a further effort to reduce the accident toll at grade crossings, the California Railroad Commission has sent out a state-wide appeal to the various highway authorities, including the boards of supervisors of all counties, to co-operate with the railroad commission in the matter of promptly apprising the commission of instances where heavy traffic, because of detours or other reasons, is thrown over grade crossings of main-line railroads normally carrying insufficient traffic to justify special protection.

With such information in its possession, the commission states, it will be in a position to have adequate special protection provided at these crossings during such periods of unusual traffic flow. It is believed that such a plan, with proper co-operation on the part of all concerned, will materially reduce the accident toll at this class of crossing.

Validity of Multiple Dwellings Law Attacked in New York

Arguments challenging the constitutionality of section 300 of the New York State multiple dwellings law were made on May 14 before the state Court of Appeals. A year ago the court upheld the validity of the law as a whole. The section now under attack provides that plans for alterations costing more than $10,000, or for a new tenement house, must be filed by the owner or a registered architect.

Oscar Goldschlag, for sixteen years a professional engineer in New York City, filed plans for a new tenement house. The department rejected the plans on the ground that Goldschlag was not an architect. This is the test case the court is asked to pass upon and comes to the highest court on appeal from the decision of Justice Mullan, who, in special term, held that the act does not "transcend the limits of the police power of the state."

"Legislation framed in the exercise of the police power," Justice Mullan said, "must be reasonable in the sense that it must be based on reason as distinct from being wholly arbitrary or capricious, but when the legislature has power to legislate on a subject the courts may look into its enactment far enough to see whether it is in any view adapted to the end attained. If it is, the courts must give it effect, however much they might, if given the choice, prefer some other measure as more fit and appropriate."

In his argument, the attorney for Goldschlag declared that the refusal of the department to receive his plans "destroys one of the most important powers and privileges inherent to the practice of the appellant's profession as an engineer, limits and circumscribes the appellant's rights of fulfilling contracts with his employers, and hampers his means of earning a livelihood."

He insisted that section 300 is "not a proper exercise of police power, but is an unreasonable and arbitrary enactment aimed at no real evil or, if there be an evil, said section has no logical approximation to end the evil to be remedied; that it creates a monopoly in a certain field of employment in favor of one profession, namely, the architect, at the expense of the profession of the engineer—a profession as well or better qualified than the architects to function in the field from which it is excluded."

Am.Soc.C.E. Appoints Delegates to World Power Conference

The American Society of Civil Engineers has appointed the following as official delegates to the World Power Conference to be held in Berlin, Germany, June 16 to 25: Arthur P. Davis, of Tashkan, Turkestan; L. F. Harza, of Chicago; Ely C. Hutchinson, editor of *Power*, New York; George A. Orrok and David B. Rushmore, New York; Charles W. Spooner, Chicago, and W. F. Uhl, Boston.

To Begin Work Soon on Atlanta's Dixie Terminal Building

Work on the $3,000,000 Dixie Terminal building to be erected in Atlanta, Ga., on the site of the old union station, will begin June 1, according to E. M. Dodds, vice-president and general manager of the United States Warehouse Co., who predicts that construction will be completed by March 1, 1931. The new building will have 150,000 sq.ft. of available cold-storage space, 300,000 sq.ft. of warehouse storage space, and 150,000 sq.ft. of office space. The E. W. Sproul Co., of Chicago, is the contractor; Fred C. Sturmer is the engineer, and J. C. Erwin, Jr., represents the building owners during construction.

Illinois Dedicates New Building for Materials Testing

Accomplishments during the quarter century which has elapsed since the founding of the engineering experiment station at the University of Illinois were commemorated at the dedication May 2 and 3 of a new materials-testing laboratory at Urbana. Tribute to the founders of the station, including Prof. Ira O. Baker, Prof. L. P. Breckenridge and Prof. A. N. Talbot, was paid by President David Kinley, retiring president of the university, in his dedicatory remarks. Professor Talbot spoke on the work in engineering materials testing, which, he said, had been devoted mainly to steel and cement, stressing the fact that now we follow the analytical rather than mathematical method of approach to engineering problems. Research investigations completed or under consideration were outlined by members of the staff. E. J. Mehren, vice-president, McGraw-Hill Publishing Co., spoke on the benefits of research to the taxpayer and to the engineering profession.

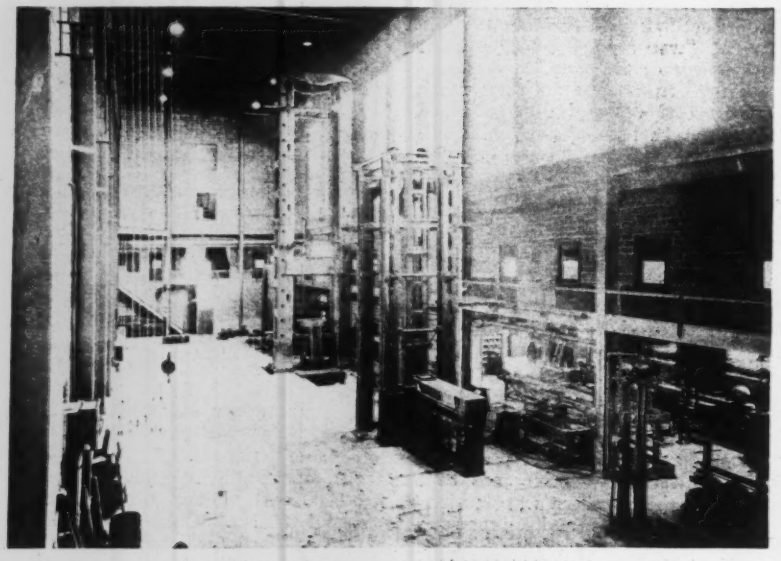
The laboratory is a four-story H-shaped fireproof structure with two wings 187x50 ft. and a stem 110x92 ft. in plan. The outstanding feature is a large laboratory room 40x147 ft. extending the full height of the building where heavy testing is done. Here is the largest testing machine of combined compression and tension character yet built; its capacity is 3,000,000 lb. The clear distance between screws is 7 ft. 6 in. and the maximum clear height from the bottom of the compression head to the top of the bed of the machine is 38 ft. 6 in. Operation is partly mechanical and partly hydraulic. The load applied is measured by means of pressure gages supplemented by an electric autographic machine producing a time-load curve. At full capacity, the oil pressure is approximately 1,800 lb. per square inch. Varying speeds can be used in applying the load, or, by means of an automatic regulator, the load can be maintained constant for a period of several hours. The machine was built and erected by the Southwark Foundry & Machine Co., Philadelphia, Pa., under license issued by the Emery-Tatnall Co.

Another feature of special interest is the roomy hydraulic laboratory with its wide, long channels and pumps having capacities of 500, 1,000 and 2,000 gal. per minute. In addition, special laboratories are provided for structural and highway materials and fatigue of metals.

Ready-Mixed Concrete Interests Plan Association

Steps leading to the formation of a National Ready Mixed Concrete Association were taken at a meeting held in Chicago, Ill., on May 16, which was attended by fifteen of the more important operators in this field, as well as by representatives of several manufacturing concerns. Those present decided that a national association is greatly needed to promote the interests of the ready-mixed concrete industry. To further the formation of such an association, an executive committee of five was appointed to canvass all producers and the entire industry in the United States and Canada. Another general meeting, at which it is expected that the actual organization of the association will take place, is to be held within 30 days.

Members of the executive committee are: chairman, J. E. Burke, Ready Mixed Concrete Co., Pittsburgh, Pa.; Alexander Foster, Jr., Charles B. Warner Co., Philadelphia, Pa.; Arthur Avril, Avril Tru-Batch Co., Cincinnati, Ohio; C. M. Cornell, Boston Ready Mixed Concrete Corp., Boston, Mass.; and Arthur A. Levison, Blaw-Knox Co., Pittsburgh, Pa.



LARGE TESTING BAY AT UNIVERSITY OF ILLINOIS
In background, 3,000,000-lb. machine; in foreground, 600,000-lb. machine

Texas Storm Causes 65 Deaths and Disrupts Water Supply

On May 6, between 3 and 4 p.m., a number of storms developed over Texas with cyclonic intensity. Much damage was caused by the storms in a number of areas, but the most damage was in a 20-mile strip more than 100 yd. wide west of San Antonio, and in a similar area in central Texas northeast of Waco and extending to points beyond Frost. Although a large part of the damage was in rural Texas, the principal destruction was in the incorporated city of Frost, which has a population of about 1,100 and which operates its own water-supply and sanitary sewer system. In that city about 40 business establishments were demolished or partly destroyed, and of the 200 homes in the town, 60 to 75 were either completely destroyed or extensively damaged. Incomplete reports show that 65 deaths resulted from the storm in all areas, 22 of these in the city of Frost.

The water supply of Frost has its source in a deep well, considered of satisfactory quality. Because of the broken taps in the demolished buildings the entire reserve supply in the elevated tank was soon used up and a corps of plumbers, aided by volunteers from adjoining towns, was kept busy for several days closing the broken connections. In the meantime the inhabitants were instructed to boil all water used for drinking purposes.

The sewage-disposal plant was little damaged, but because of the fact that nearly one-half of the connections were broken or out of commission through lack of running water or stoppage, a serious sanitary problem existed for a time.

An excellent example of what can be done by concerted effort under the direction of trained experts was furnished at Frost. The State Department of Health, engineering division, jointly with the Red Cross, quickly commandeered half a dozen volunteer sanitary engineers from near-by points, who, working under the direction of E. C. Eggert, sanitary engineer, State Department of Health, quickly cleared up the situation.

Soper Leaves to Study Foreign Waste-Disposal Methods

At the request of the Committee of Twenty on Street and Outdoor Cleanliness, appointed by the New York Academy of Medicine to help make New York a clean city, George A. Soper, consulting engineer and member of the committee, left New York on May 21 to make a study of municipal sanitation among the cities of Europe. During his trip Mr. Soper will attend an international congress of municipal cleansing authorities at Stuttgart, and the Hygienic Exposition at Dresden, Germany. He will also visit Italy before his return to the United States.

Water Company Plant in New Jersey Appraised at $14,000,000

Valuation of the holdings of the Passaic Consolidated Water Co. in Paterson, Passaic and Clifton, N. J., has been put at $14,000,000 in condemnation proceedings in behalf of the three municipalities. The property includes the historic rapid filtration plant built a quarter century ago by the East Jersey Water Co., also works originally owned by the Passaic Water Co., of Paterson, and the Acquackanonk Water Co., of Passaic. It is reported that both the municipalities and the water companies will appeal to the court for a revision of the valuation. All three of the cities are partners in the Wanaque project carried out for them, Newark and four other communities by the North Jersey District Water Supply Commission.

Mid-South Engineers Hold Annual Meeting at Little Rock

Flood control, transportation and power development were the general subjects discussed at the annual convention of the Mid-South section, American Society of Civil Engineers, held at Little Rock, Ark., on May 15 and 16. Major L. D. Worsham, U. S. Engineer Office, Memphis, described the flood-control studies being made by his office on the tributaries of the Mississippi River in the Fourth Field Area, comprising parts of Arkansas, Oklahoma, Texas, Tennessee, New Mexico, Colorado, Kansas and Missouri. He discussed the use of reservoirs as flood-control agents. The fact was brought out that the construction of a dam at Big Rock, near the city of Little Rock, would produce a reservoir quite suitable for flood reduction in the mid-valley territory. Such a reservoir, had it been in operation during the 1927 flood, would have caused a reduction of 6.25 ft. on the Arkansas City (Ark.) gage, assuming that the levees had held. However, Major Worsham pointed out that such a dam would cost approximately $47,000,000 per foot of gage reduction and that many towns and villages would be inundated. Discussion of these questions was carried on by Gen. T. H. Jackson, Vicksburg, Miss., and Col. F. B. Wilby, Memphis.

E. A. Hadley, chief engineer, Missouri Pacific Lines, St. Louis, discussed the effect the operation of private bus lines and automobiles has had on the railroad's passenger traffic. Government-subsidized inland waterways transportation was also compared with freight service by the railroads, with particular reference to operation and overhead costs. J. H. Haylow, chief engineer, Memphis Street Railway, Memphis, spoke on traffic conditions, with particular reference to automobile accident-prevention measures. A. J. Hammond, consulting engineer, Chicago, vice-president of the parent society, discussed the society's functional expansion program which is now under way.

On May 16 the attending members motored to Hot Springs and inspected the gravity section concrete dam being built near that city by the Phoenix Utility Co. for the Arkansas Power & Light Co. L. G. Warren, superintendent of construction, stated that the dam would give a 92-ft. operating head and produce 80,000 hp. The 150,000 cu.yd. of concrete is being batched by weight. Water-cement ratio control is used.

At the closing meeting at the Kingsway Hotel, Hot Springs, new officers were installed, as follows: N. B. Garver, Little Rock, president; K. W. Markwell, Memphis, secretary-treasurer; O. G. Baxter of Little Rock, Col. J. R. Fordyce of Hot Springs, G. W. Miller of Memphis, H. S. Gladfelter of Memphis, Major P. S. Reinecke of Vicksburg, Prof. J. H. Dorroh of University, Miss., as vice-presidents.

The Business Outlook

After several weeks of stagnation, business appears to have freshened a little and has resumed its slow and irregular climb back to normal. Although basic industrial activity has entered upon a period of seasonal decline, it is holding slightly above the level of seasonable expectations, and general trade shows considerable improvement.

***The Business Week's* preliminary index of general business activity has risen to 97 per cent of normal, as compared with the final revised figure of 94.2 per cent for the preceding week.**

—The Business Week, May 21.

Control of Missouri Pacific Ry. Passes to Van Sweringens

Following approval of the Missouri Public Service Commission of the acquisition of control of the Missouri Pacific Railroad by the Allegheny Corporation, the holding company of the Van Sweringen interests of Cleveland, the Van Sweringen interests have taken over control of the railroad's operations by putting eight of their own men on the board of directors.

The Van Sweringen interests now control the Erie, the Chesapeake & Ohio, the Pere Marquette, the Chicago & Eastern Illinois and the Missouri Pacific. Control of the Missouri Pacific carries with it joint ownership of the Denver & Rio Grande Western, thus extending the Van Sweringen control as far west as Salt Lake City.

Control of the Western Pacific, which owns the other half of the stock of the Denver & Rio Grande Western, would give the Van Sweringen interests a transcontinental line, but Arthur Curtiss Janes, who controls the Western Pacific, is said not to favor such an affiliation, preferring to have the Western Pacific remain independent.

WASHINGTON NOTES

By Paul Wooton
Washington Correspondent

Committee Considering Boulder Dam Appropriation—Hearings on Rivers and Harbors Bill

ARGUMENTS in favor of an appropriation of $10,660,000 to start work at Boulder dam were presented last Monday, May 19, before the House committee on appropriations by Secretary of the Interior Wilbur and by Elwood Mead, chief of the bureau of reclamation. As usual with appropriation matters, the hearing was behind closed doors. More than usual secrecy surrounded the proceedings, with contestants on both sides of the controversy unwilling to release their talking points in advance.

During the hearing on Tuesday, Arizona witnesses presented their arguments against the approval of the fund requested by the Interior Department. It is understood that the main line of attack was directed against the contracts whereby the department has sought to underwrite the project power output as required under the terms of the Boulder Canyon act. Arizona delegates had voiced objections to some of the contract provisions prior to the hearings. They have doubted the power of Los Angeles to enter agreement and of Secretary Wilbur to contract for water delivery to the Metropolitan Water District outside of the Colorado basin. The latter argument is based on the Chicago diversion case decision of the Supreme Court.

Adjournment of the hearing was taken till Friday, May 23. During the interim, counsel for the Interior Department was to examine the objections and to report on their probable validity. From the present outlook it still seems likely that the appropriation will be granted and that Arizona's redress will come through the courts.

President Praises Ransdell

Formal recognition of the service performed by Senator Ransdell, of Louisiana, in having secured the passage of legislation creating a national hydraulic laboratory was given by President Hoover in a public statement May 16. The President called attention to the persistence of Senator Ransdell during eight years in keeping this legislation before Congress and thereby making a most important contribution to the solution of water problems.

Research Program for Airports

The American Engineering Council and the American Road Builders' Association will co-operate with the aeronautics branch of the Department of Commerce in a broad research program covering the design, construction and operation of airports. These organizations have had the project under consideration for the past six months and now are ready to proceed with a view to

preparing a comprehensive report for future guidance in the development of airports. A joint committee will be created at once and such subcommittees will be organized as may be necessary to carry on the program. A study of the coverage and drainage of airports is scheduled for immediate execution.

Hearings Nearly Completed on Rivers and Harbors Bill

Public hearings on the rivers and harbors bill have been practically completed. The major changes that have been recommended in the bill so far deal with the Missouri River and the Illinois waterway. Those interested in improving the Missouri River between Sioux City and Kansas City have asked that the amount provided for this work in a House bill be increased from $15,000,000 to $25,000,000. This increased appropriation is justified by the importance of securing cheaper transportation for the upper Missouri Valley, it is stated. The committee was informed by Cleveland Newton, president of the Mississippi Valley Association, that an increased appropriation for the upper Missouri would allow efficient use to be made of river equipment that has finished its work on the section of the river below Kansas City.

It is not believed that any major disagreement will arise over the Lakes-to-the-Gulf waterway project, since Senator Vandenberg, leader of the Lake states group, has indicated that he is not opposed to the waterway in principle but only questions the advisability of providing blanket authority for diverting water from Lake Michigan. General Brown told the committee that the language of the bill which allows the War Department to divert enough water for the "development of a commercially useful waterway" must not be construed as meaning that the engineers will take an excessive amount. He also stated that he is of the opinion that no definite amount of diversion should be fixed upon at this time. He believes that a future study of the completed waterway should be made to ascertain the quantity of water necessary for navigation.

It was brought out by General Brown that the depth of the water in the lower reach of the Illinois River, where no canalization will be done, will depend upon the amount of diversion from Lake Michigan. Should the entire diversion be reduced to 1,000 sec.-ft., canalization will be necessary, with accompanying costs which will vary in inverse ratio to the quantity of diversion, he said. He also stated that prior estimates indicate that complete canalization would cost $5,000,000, based on 1,000 sec.-ft. diversion and $1,000,000 if a flow of 10,000 sec.-ft. is allowed.

C. & O. Seeks Extension

The Chesapeake & Ohio Railway has applied to the Interstate Commerce Commission for permission to construct a 4.5-mile extension of its Logan subdivision in Mingo County, W. Va. Extending from West Gilbert up Gilbert Creek, Horsepen Creek and Browning Fork, the new trackage will serve an area of 12 square miles of coal lands estimated to contain 40,000,000 tons of high-grade bituminous. The present line up the Guyandot River was completed to Gilbert in June, 1923. The C. & O. states that the coal deposits tributary to the projected line are in great demand and that mining operations will commence as soon as construction is completed.

Obituary

JOHN H. SCOTT, civil engineer, of Seattle, Wash., died in that city on May 14, age 77 years. Mr. Scott was a graduate of the Massachusetts Institute of Technology, and, going west, became city engineer of Ellensburg, Wash. In later years he was engaged in private practice in Seattle.

JOHN G. THEBAN, of New York City, died on May 13 at the age of 69. Upon being graduated from the St. Francis Xavier College in 1890, Mr. Theban became a civil engineer for the New York Central Railroad. In 1900 he entered the employ of the Department of Plant and Structures of New York City. For the greater part of his seventeen years in the department, he had charge of maintenance and construction in the Bronx.

LANSING C. HOLDEN, retired architect, of New York City, died at his summer home near Carmel, N. Y., on May 15 after a month's illness of pneumonia. He was 72 years old. Mr. Holden served on various committees in the American Institute of Architects and was largely responsible for the adoption of the Institute's code of ethics in its present form. He was elected a fellow of the Institute in 1912 and had been president of the New York Chapter. He was a member of the board of examiners of the city of New York in 1916 and a member of the board of standards and appeals from 1916 to 1918. He had also served as architect for the Lackawanna Railroad.

ALBION L. GRANDY, assistant to the vice-president (and formerly chief engineer) of the Pere Marquette Railway, died suddenly at his home in Detroit, Mich., on May 10. Mr. Grandy was born at Barton's Landing (now Orleans), Vt., in 1867, and was graduated from St. Johnsbury Academy in 1884. He began his railroad career on the Frankfort & South Eastern Railroad, which later became the Ann Arbor Railroad. In 1889 he joined the engineering staff of the Chicago & West Michigan Railroad and in 1900 went to the Erie Railroad as roadmaster. A short time later he became assistant bridge engineer of the Pere Marquette Railway and then successively filled the posts of division engineer, chief engineer, assistant general manager and assistant to the president and, later, assistant to the vice-president. Mr. Grandy was a member of the American Railway Engineering Association.

CLAUDE IRVIN RHODES, vice-president of the Loveland Engineers, Inc., San Francisco and Los Angeles, Calif., died in Berkeley, Calif., on May 11. Mr. Rhodes was closely identified with the work of rebuilding San Francisco after the earthquake and fire of 1906 and devoted more than three years to the inspection of materials for, and the installation of, sewers, public buildings, the high-pressure fire system, reservoirs, pavements and other works. Later he was placed in charge of the construction and operation of the water-supply and gas systems for the Panama-Pacific Exposition. From 1918 to 1923 Mr. Rhodes was associated with the hydraulic division of the California Railroad Commission, serving as chief hydraulic engineer for the last two years of this period. In 1923 he joined the Loveland Engineers, Inc. Mr. Rhodes was a member of the American Water Works Association, the Engineers' Club of San Francisco and the American Society of Civil Engineers.

Society Calendar

AMERICAN SOCIETY FOR TESTING MATERIALS, Philadelphia; annual meeting, Atlantic City, N. J., June 23-27.

AMERICAN SOCIETY OF CIVIL ENGINEERS, New York; annual convention, Cleveland, Ohio, July 9-11.

AMERICAN WATER WORKS ASSOCIATION, New York; annual meeting, St. Louis, Mo., June 2-6.

INTERNATIONAL CONGRESS OF BUILDING AND PUBLIC WORKS, London; fifth congress, London, England, May 26-30.

NATIONAL SAFETY CONGRESS, Chicago; annual meeting, Pittsburgh, Pa., Sept. 29-Oct. 3.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION, Pittsburgh, Pa.; 38th annual meeting, Montreal, Canada, June 26-28.

WORLD POWER CONFERENCE, second plenary meeting, Berlin, Germany, June 16-25. American secretary, O. C. Merrill, Washington, D. C.

Costs and Contracts

E. N.-R. Index Numbers

Cost			Volume		
May 1,	1930	205.86	April,	1930	351
Apr. 1,	1930	207.12	March,	1930	408
May 1,	1929	205.15	April,	1929	332
Average,	1929	207.02	Average,	1929	317
Average,	1928	206.78	Average,	1928	287
1913	.....	100.00	1913	.....	100

This Week's Contracts

Heavy construction contracts, reported by *Engineering News-Record* in the week of May 22, with some comparisons, total as follows:

(In Thousands of Dollars)

	May 22, 1930	Average Preceding Four Weeks 1930	1929
Buildings:			
Industrial	$15,175	$12,115	$14,466
Other	27,295	46,443	42,242
Streets and roads..	17,068	17,730	17,501
Other eng. constr..	28,156	18,950	20,319
Total	$87,694	$95,237	$94,527
Total, all classes, Jan. 1 to May 22:			
1930			$1,517,454
1929			1,856,839

Prices of Water-Works Materials

Chemicals for Water Purification

(Prices at Works)

	May, 1930	Avg. 1929
Aluminum sulphate or commercial alum—per 100 lb. in bags	$1.40–$1.45	$1.40
Production in 1927: 22 plants, 314,018 tons; value $8,012,626; consumption for water purification, 60%.		
Chlorine, liquid—per 100 lb. in tank cars	2.50	2.75
Per 100-lb. cylinders	4.50	
Production in 1927: 15 plants, 234,978,522 lb.; for sale, 180,163,438 lb.; value, $6,678,145; consumption for water and sewage, 10%		
Copper sulphate—per 100 lb. bbl.	5.50	6.00
Production in 1927: 11 plants, 56,666,812 lb.; value, $2,774,400; distribution for water purification, 15%		
Copperas or ferrous sulphate—per ton	14.00	15.00
Production in 1927: 32 plants, 61,527 tons; value, $672,918; for water purification, 10-15%		
Lime, chemical grade—per ton	8.50	8.50
Production in 1927: 2,287,177 tons quicklime; 1,461,650 tons hydrated; consumption for water purification, 100,000 tons		
Soda ash—per lb. in bags	1.32	1.32
Dense	1.35	
Production in 1929 (*C. & M.*), 1,668,000 tons; in 1927: 12 plants, 1,446,379 tons; value, $29,939,291; consumption for water purification, 60,000 tons		

Pipe

Steel, standard, carloads, at Pittsburgh or Lorain mills, random lengths, net, per ft.:

Inside Dia., In.	Outside Dia., In.	Black		Galvanized	
		Current	Year Ago	Current	Year Ago
1.049	1.315	$0.062	$0.065	$0.081	$0.085
1.38	1.66	.083	.088	.11	.114
1.61	1.9	.099	.105	.131	.137
2.067	2.375	.134	.141	.176	.184
2.469	2.875	.211	.223	.278	.29
3.068	3.5	.276	.291	.364	.379
3.548	4.0	.359	.378	.465	.483
4.026	4.5	.426	.447	.551	.573
5.047	5.563	.578	.607	.748	.777
6.065	6.625	.749	.788	.97	1.008

Foregoing prices are net, the current discounts having been subtracted. These discounts are 64% for black and 52½% for galvanized on 1- to 3-in. butt-weld; 61% black and 49½% galvanized on 3½- to 6-in. lap-weld.

Clay drain pipe, carloads, f.o.b. New York, per ft.:
6-in. $0.08 12-in. $0.30

Wrought-iron pipe, carloads, f.o.b. Pittsburgh, galvanized, net, per ft.:
¾-in. $0.103 1¼-in. $0.196 2-in. $0.304
1-in. .145 1½-in. .226

Riveted steel pipe, 36-in., 30 ft. lengths, f.o.b. New York, per ft. $20.00

Concrete pipe, steel reinforced, mesh or plate, 100-ft. head, delivered to trench side in Metropolitan District, per ft.: 30-in. $6.00, 48-in. $12.00.

Spiral riveted pipe, 30-ft. lengths, 110 lb. pressure, asphalt coated, with flanged joints, net, f.o.b., New York, per ft.:

6-in., 16 gage	$0.72
12-in., 14 gage	1.40
16-in., 12 gage	2.30

Centrifugally spun iron pipe takes the following discounts from price of pit-cast pipe, to give the price per linear foot:

Size, In.	Class 150	Class 200	Class 250
4	15%		10%
6	15%		10%
8, 10 and 12	15%	10%	7½%

Cast-iron, Class B and heavier, bell-and-spigot, f.o.b. in regular lots, per net ton:

	4-In.		6-In. and Over	
	Current	Year Ago	Current	Year Ago
Birmingham, Ala.	$40.00@	$41.00	$41.00	$37.00@ $38.00	$38.00
Burlington, N. J.	40.00	41.00	37.00	38.00

Class A, $3.00 per ton extra

Flexible-joint pipe, base, full lengths, f.o.b. Florence, N. J., per net ton, $62. Differential: $25 per net ton above base price for Class B, pit-cast pipe.

Cement-lined pipe, f.o.b. Lynn, Mass., per 100 ft., net:

Size, In.	Steel		Wrought Iron	
	Black	Galvanized	Black	Galvanized
¾	$11.27	$14.26	$17.48	$20.93
1	16.32	20.06	23.80	29.07
1¼	22.08	27.14	32.20	39.33
1½	26.40	32.45	37.40	45.65
2	35.52	43.66	51.80	62.90
2½	56.16	69.03	78.39	93.60
3	73.44	90.27	97.92	117.81

Lead-lined fittings for cement-lined pipe, each:

	Couplings		Washer Unions	
	Black	Galvanized	Black	Galvanized
¾	$0.162	$0.186	$0.432	$0.51
1	.21	.24	.54	.642
1¼	.318	.366	.69	.84
1½	.438	.504	.87	1.05
2	1.60	.738	1.08	1.32
2½	.93	1.14	1.68	2.16
3	1.20	1.50	2.40	3.00

Steel casing for water wells, consumers' carloads, at Pittsburgh or Lorain mills, net, per ft., in cut lengths over 9 ft.:

Inside Dia., In.	Outside Dia., In.	Lb. per Ft.	Current	Year Ago
2	2⅜	2.34	$0.228	$0.235
3	3½	4.1	.283	.292
3¼	3⅝	4.6	.304	.313
4	4½	6.2	.41	.422
4¼	4⅝	6.75	.418	.432
4¾	5	8.0	.495	.511
5	5¼	8.5	.544	.561
5⅝	6	10.50	.672	.693
6¼	6⅝	12.00	.744	.768
6⅝	7	13.00	.837	.864
7¼	7⅝	14.75	.859	.888
8¼	8⅝	17.50	1.015	1.05
8⅝	9	19.00	1.169	1.207
9⅝	10	22.75	1.46	1.505
10⅝	11	26.75	1.716	1.769
11⅝	12	31.50	2.016	2.079
12½	13	36.50	2.336	2.409

Foregoing prices on well-casing are net, the current discounts on cut lengths over 9 ft. having been subtracted. These discounts range from 31% for 2- to 3-in., to 42% for 7¼- to 8¼-in. and 38½% for 8⅝-in. and 36% for 9⅝- to 12½-in. For random lengths the discounts are 6 points more on 2- to 4-in. and 4½ points more up to and including 8¼-in. Discounts on galvanized well-casing are 13 points lower.

Deoxidized copper tubes, for use with compression fittings, quantity lots, f.o.b., Waterbury, Conn., in lengths up to and including 30 ft., net, per ft.:

Size, In.	Price	Size, In.	Price
⅜	$0.115	1¼	$0.35
½	.1375	1½	.46
¾	.23	2	.675
1	.2825		

Prices of Water-Works Materials

Pipe wrapping, for underground steel water pipe of large diameter, single-ply felt with two coatings of bituminous cement, f.o.b. New York, per sq.ft. of area $0.06

Red brass pipe—(85% copper) in quantity lots, f.o.b. Waterbury, Conn., net, per lb.:

Size, In.	Price	Size, In.	Price
4	$0.25625	6	$0.31925
4½	.28325	7	.33725
5	.31025	8	.35525

Supplies

Valve boxes, ordinary length, 4- to 5½-ft. trench, f.o.b., East Orange, N. J. $6.50@$8.50

Fire hydrants, New York type, f.o.b. East Orange, N. J., approximately, each $60.00

Feed-water filters, single unit, boxed, f.o.b. Troy, N. Y., net:

Size, In.	Price	Size, In.	Price
1	$150	3½	$450
1½	175	4	500
2	250	4½	600
2½	300	5	700
3	375	6	800

Venturi tubes, standard, cast-iron, 125 lb. pressure, f.o.b. Providence, R. I., each: 6-in., $125; 12-in., $285; 48-in., $3,170.

Remote indicator for showing actual water-head or difference in head between forebay and afterbay, f.o.b., Long Island City, N. Y., each $90

Remote recording meter, equipped with two adjustable alarm contacts, either 24-hr. or 8-day clock for 24-hr. or 7-day charts, f.o.b. Long Island City, N. Y., each $120

Filtration sand, carloads, f.o.b. Metropolitan Dist., per ton.. $6.00

Water meters, in lots of 100, f.o.b. New York, net, each:
⅝-in. $12.60 ¾-in. $12.90
Connection for ⅝-in., each 1.00 For ¾-in. 1.50

Meter boxes, lots of 100, 20-in. base, f.o.b., New York, net, each:
Flat type, 5-in. deep $5.75 Bell type, 10½-in. deep.... $7.25

Valves, 6-in. in lots of 1,000, f.o.b. New York, each. $25.00

Tapping sleeve and valve, f.o.b. East Orange, N. J., net, each:

	Sleeve and Valve	Cross Sleeve and Two Valves
4x 2-in	$16.00	$27.20
8x 8-in	64.00	111.20
12x12-in	121.60	204.80

Building Materials

	Boston	New York	New Orleans	San Francisco
Cement, net, bbl.	$2.50	$2.15	$2.65	$2.64
Sand, del., ton	1.25	2.15*	2.75*	1.75
Gravel, del., ton ¾-in	1.90	3.40*	3.75*	1.75
Crushed stone, del., ton ¾-in..	2.10	3.40		1.65
Brick, del. M.	17.00	15.00	16.50	14.50
Pine timbers, del. M	60.00	74.00	67.00	33.00†

*Per cubic yard; †Douglas fir.

	—Pittsburgh— Current	Year Ago	Birmingham Current	Year Ago
Reinf. bars, 100 lb. mill	1.85	2.00	2.15	2.15
			Chicago	
Steel wire reinf., base, 100 sq.ft..	.99	.99	1.01	1.01

Slate roofing, f.o.b. quarry, Bangor, Pa., net, per square:

	Current	Year Ago
No. 1 clear	$9.45@$13.05	$10.50@$14.00
No. 1 ribbon	8.10@ 9.23	9.00@ 10.25
Medium clear	8.55@ 10.13	9.50@ 11.25

Asphalt, f.o.b. Maurer, N. J., per ton in packages:

	Current	Year Ago
Bermudez	$30.00	$30.00
Trinidad	25.00	25.00

Lead, pig, per lb.:

	Current	Year Ago
East St. Louis refinery	$0.0545	$0.068
New York, warehouse	.065@.07	.0825

Lead, red or white, dry, and litharge, f.o.b. per 100 lb. keg:

	Current	Year Ago
New York	$13.75	$13.75

Linseed oil, raw, f.o.b., in 1 to 4-bbl. lots, per lb.:

	Current	Year Ago
New York	$0.148	$0.109
Chicago	.15	.113

Steel sheetpiling, base, large lots, f.o.b. Pittsburgh mill, per 100 lb. $2.25

Jointing Materials

Lead wool, lots of 2,000 lb. f.o.b. New York, per lb., $0.09½
Oakum in 50-lb. bbl., 6-bbl. lots, f.o.b. New York, per lb. .08½

Hydrotite, 100 lb. cloth bags, f.o.b. Boston, per lb. $0.10
Keytite, half-barrel or barrel lots, f.o.b. East St. Louis, per lb. $0.16

Prices of 1930 Contracts

Diesel-engine-driven generator—New Orleans Sewerage and Water Board let contract April 30, 1930, for 700 to 800 kw. set for Pumping Station C. Twelve bids were received, ranging from $73 to $118 per kw., of which the lowest four are given below. The engine is of the vertical-cylinder diesel type, with normal speed of 250 r.p.m., is direct-connected to a 6,600-volt, 25-cycle generator, and the complete unit has 20 per cent overload capacity for two hours.

	Generator Capacity, Kw.	Price per Kw.	Fuel Rate— Full Load	¾ Load	½ Load	No. of Cyls.	Bore x Stroke
1	720	$73.00	0.59	0.62	0.675	7	16 x20
1	825	72.75	.59	.62	.675	8	16 x20
	(800)	(75.02)					
2	715	76.30	.60	.64	.70	8	18 x24½
3	750	84.66	.58	.61	.66	8	17 x26
4	800	86.482	.585	.595	.645	8	17½x26

Chemicals

Chlorine; 10 cars for Minneapolis filtration plant; $4.99 per 100 lb.

Burnt lime for St. Louis Water Dept.; 12,000 tons at East St. Louis, $7.33; 11,000 tons at Hine, $8.50.

Sulphate of iron for St. Louis; 3,000 tons @ $13.05.

Sulphate of aluminum for St. Louis; 4,400 tons @ $17.50.

Liquid chlorine for St. Louis; 230,000 lb. @ $2.875 per 100 lb.

Concrete Pipe

South Dakota State—1,288 ft. 15-in. @ $0.66; 3,988 ft. 18-in. @ $0.81; 2,356 ft. 24-in. @ $1.30; 1,212 ft. 30-in. @ $1.95; 532 ft. 36-in. @ $2.83; 68 ft. 42-in. @ $3.95; 112 ft. 48-in. @ $4.56. To another company: 1,112 ft. 15-in. @ $0.60; 8,512 ft. 18-in. @ $0.80; 6,144 ft. 24-in. @ $1.20; 2,788 ft. 30-in. @ $1.85; 1,218 ft. 36-in. @ $2.75.

Cast-Iron Pipe

Boston—100 tons 6-in., 500 tons 8-in., 1,400 tons 12-in., 50 tons 54-in., Class B, @ $84.317; 10 tons special castings, 50 tons bell-and-spigot, @ $74.80; 13,000 lb. No. 1, 20,000 lb. No. 2, 5,000 lb. No. 3 composition castings, @ $0.278.

Glendale, Calif.—4,800 ft. 20-in. B, 175 lb. @ $3.8625; 3,600 ft. 24-in. B, 233.3 lb., @ $5.15; 2,900 ft. 24-in. C, 279.2, @ $6.165; 300 ft. 30-in. B, 333.3, @ $7.525; 40 tons Class B and D fittings, @ $80; 10,000 ft. 6-in. Class 250 sand-spun centrifugal, 26.8 lb., @ $0.64; 3,000 ft. 12-in. Class 250, 66.5 lb., @ $1.76.

Turlock, Calif.—500 ft. 6-in. @ $0.614; 800 ft. 8-in. @ $0.867.

Santa Ana, Calif.—15,000 ft. 4-in. @ $0.397; 11,000 ft. 6-in. @ $0.579; 4,500 ft. 8-in. @ $0.815; 3,000 ft. 10-in. @ $1.094; 6,300 ft. 12-in. @ $1.43.

Toronto, Ont.—Ninety-four 12-ft. lengths 36-in. @ $148.75 per length.

Unit Prices From Current Construction Bids

Land Tunnel and Structures Connecting Detroit River and Spring Wells Station

THE most recent elements of the additional water-supply system for Detroit to be placed under contract are the land tunnel and structures of the intake system (RC-12) and the pumping plant and filter building of Spring Wells station (GC-1). Contract RC-12 completes the 10-mile concrete tunnel connecting the new station with the Detroit River. The work comprises (1) a circular screen chamber 64 ft. in diameter in Water Works Park; (2) 628 ft. of 15½-ft. tunnel connecting the shore shaft and screen chamber; (3) 131 ft. of 11-ft. tunnel connecting the screen chamber and the auxiliary low lift plant; (4) 1,837 ft. of 14-ft. tunnel connecting the screen chamber and the Pennsylvania Ave. tunnel at Jefferson Ave.; (5) two stop-log shafts. Contract RC-12 was let April 9, 1930, to the Dravo Contracting Co., Pittsburgh, for $583,530. Contract GC-1, for pumping plant, filter building and clear water conduit, was let May 9 to the Bryant & Detwiler Co., Detroit, for $1,232,082.

Characteristics of the three tunnels, all circular, are given in the following table:

Inside Dia., Ft	Thickness Lining, In.	Cubic Yards Per Foot Excavation	Cubic Yards Per Foot Concrete
15½	28	11.8303	4.8417
14	25	9.6001	3.8987
11	20	5.9761	2.4564

Plant Site—The accompanying illustration shows the layout of the plant and tunnels. Attention is directed to the coal barge canal extending from the Detroit River to the coal-storage building. As this canal is used during the navigable season for delivering coal to Water Works Park station, the contractor must carry pipe and power lines across the canal in a manner not to interfere with the delivery of coal. Trucking over the swing bridge which crosses the canal near the screen chamber is not permitted. The sites for the two stop-log shafts and a connecting roadway on the west side of the canal are in a portion of the park used extensively by the public for recreation and surrounded by shade trees. The contractor must avoid inconveniencing the public, protect the shade trees for which he is responsible, and erect a 6-ft. board fence around these sites. He must build and maintain access roads to the shaft sites and remove them on completion of the contract.

Order of Work—The order of constructing the various elements of contract RC-12 is as follows:

1. The 15½-ft. tunnel, the screen chamber and the 14-ft. tunnel are constructed simultaneously.

2. For the screen chamber: (A) open-cut to El. 89.5; (B) sinking the eight wells and placing concrete landing piers for the screen chamber caisson; (C) sinking caisson; (D) constructing quarter-bend below foundation slab; (E) driving foundation piles and completing screen chamber.

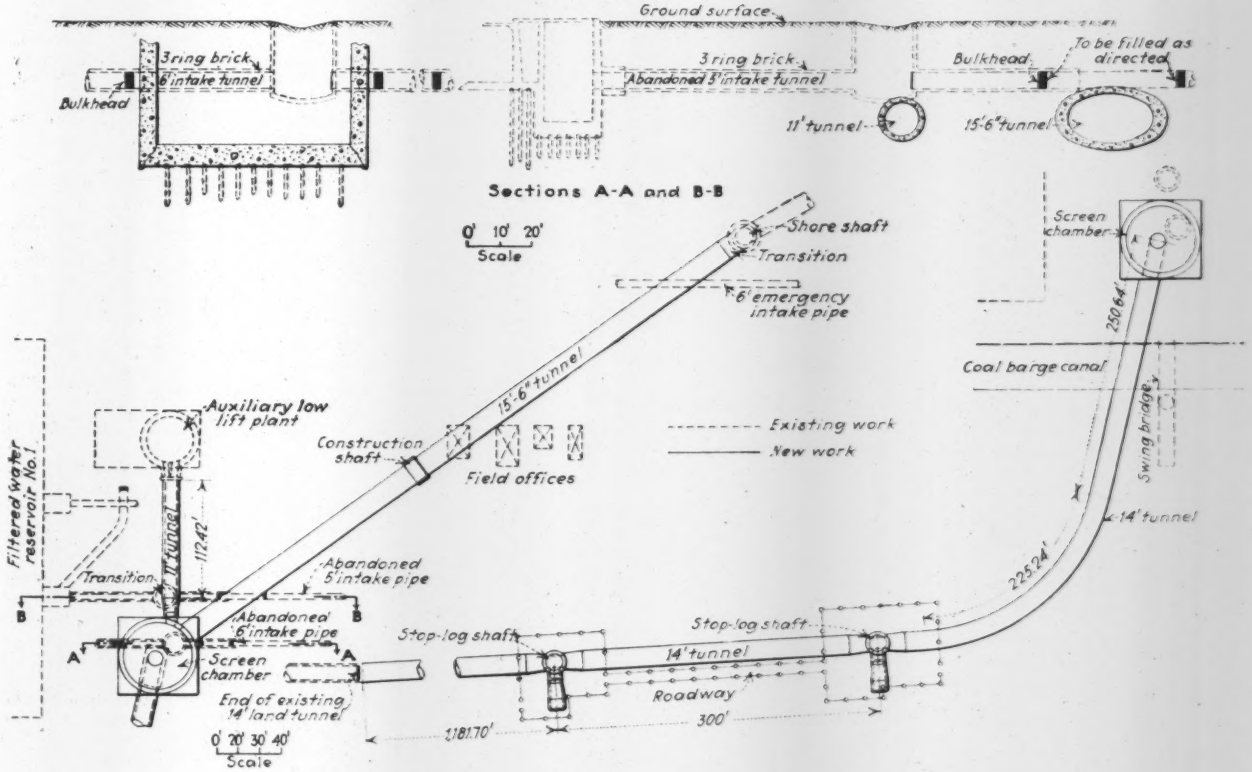
3. For the 15½-ft. and 14-ft. tunnels: Follow normal sequence modified by the character of the structures and the methods of shaft-sinking and tunneling used. The 14-ft. tunnel is driven simultaneously from two headings.

4. Completing the remaining work: Time of driving the 11-ft. tunnel will depend on progress made in constructing the screen chamber, and it may be necessary to drive this tunnel from a point outside the chamber.

Use of Compressed Air—Compressed air is required for constructing the 15½-ft. and 14-ft. tunnels, and no operations are permitted on the former until air-locks have been installed in the construction shaft. As soon as a sufficient length of tunnel has been driven and lined, the tunnel locks must be installed. No extra payment is allowed for operations in compressed air. Shifts and intervals of work for each 24-hour period are tabulated below:

Pounds Per Square Inch	Hours Under Pressure: Maximum Total	Maximum First Shift	Minimum Rest	Maximum Second Shift
Greater than normal and up to 21	8	4	2	4
Greater than 21 and up to 30	6	3	1	3
Greater than 30 and up to 35	4	2	2	2

All machinery and tools are operated by electricity, compressed air and other approved power, and animal transportation or gasoline locomotives are not permitted in the tunnel. An electric power line has been built on the east side of the canal primarily for use in constructing the river tunnel. The present unused



LOCATION PLAN OF LAND TUNNELS FOR DETROIT RIVER WATER SUPPLY

capacity of 150 hp. is available for constructing the land tunnel and structures.

Shaft Excavation—Item 1 of the accompanying unit prices tabulation consists of sinking the two stop-log shafts of the 14-ft. tunnel; the eight wells for the landing piers; the construction shaft for the 15½-ft. tunnel, and the stop-log well for the 11-ft. tunnel; furnishing, placing and removing sheeting, bracing and timbering; provision of sheeted, floored and covered drainage sumps at the bottom of the shafts; pumping and ventilating; restoration of surface and subsurface structures; backfilling of the shaft excavation outside of the concrete, and the exclusion of surface water from the shafts.

Air-Compressing Plant and Locks—Item 2 includes furnishing, installing and maintaining during tunneling a complete air-compressing plant, and air-locks in the shaft of the 15½-ft. tunnel and in all tunnel headings except the 11-ft. tunnel. The estimate is lump sum, and charges arising from the use of the plant and locks are included under Item 3, Tunnel Excavation. There must be at least four air compressors, each of capacity not less than 950 cu.ft. at 30 lb. above atmospheric pressure at any tunnel heading. The driving units must have 15 per cent greater brake horsepower than required for the operating pressure. Duplicate air feed pipes are required, so laid out that either heading at a shaft may be supplied through any pipe. Air-locks for the 14-ft. tunnel withstand 30 lb., and for the 15½-ft. tunnel 25 lb. per square inch. For air pressures of more than 15 lb. man-locks may be required. Upon the first payment, title to the air plant goes to the board of water commissioners, and upon completion of the work reverts to the contractor.

Tunnel Excavation—Item 3 includes excavation of the three tunnels and the stubs at the stop-log shafts. The type and amount of timbering depend upon the conditions encountered. A working floor is provided of 2-in. planks laid across stringers. Keeping the tunnel dry is included in the cost of this item. Attention is called to the river tunnel being driven from the shore shaft under another contract. Care is required in approaching this shaft with the land tunnel, and before excavating the last 25 ft. the contractor must obtain approval of his method of making the connection.

Excavation for Screen Chamber—Item 4 includes removal of of materials necessary for the construction of the screen chamber and quarter-bend connecting the 14-ft. tunnel to the chamber, and these materials include a 6-ft. brick conduit adjacent to the screen chamber. It also includes sheeting, timbering and pumping, and the backfilling of the excavation outside the finished structures. Above El. 89 excavation is in open-cut, and below by caisson. Payment for the steel cutting shoe is made under Item 14, Structural Steel. Landing piers for arresting the progress of the caisson at required elevation are provided under Item 1 and Item 9 (Concrete). The contractor may suggest other ways of arresting the caisson provided they do not increase expense. Excavation for the quarter-bend connecting the 14-ft. tunnel to the screen chamber is in open-cut and supported by steel sheetpiling, wales and struts. Payment for supports left in place is covered by Items 16 and 19.

Concrete—Concrete is used for lining the shafts and tunnels and the screen chamber and quarter-bend. The mix is 1 : 2 : 3, with maximum water content 6½ gal. per sack of cement. Minimum mixing time is 90 seconds. Concrete is placed within 30 minutes after mixing, and retempering is not permitted. The vertical distance through which concrete may be dropped into the forms without the use of drop-chutes must not exceed 5 ft. No concrete is placed in water. Exposed surfaces are wetted twice a day for seven days, beginning twelve hours after placing. The bottom of forms for beams, girders and floorslabs are coated with ½ in. of mortar before concrete is placed. Schedule for moving the forms is as follows: Shafts and tunnels, as directed; walls, three days; piers three days; sides of beams and girders, six days; shores under beams and girders, ten days; shores under floorslabs, fourteen days.

For concrete placed in caissons for the shafts and the screen chamber a minimum strength of 1,600 lb. per square inch in compression is required.

Forms for the interior of shaft linings may be of metal or wood lined with galvanized sheet metal of No. 23 gage or heavier, fastened with thin-headed barbed roofing nails ¾ in. long. Forms for lining the 14-ft. tunnel are metal except those that are to be used only once, which may be of wood. For the 15½-ft. and 11-ft. tunnels and the stubs the forms are of wood lined with galvanized sheet steel.

Items 9 and 10 cover the cost of concrete for the quarter-bend, the screen chamber and other open-cut work. Class A concrete includes all concrete in the quarter-bend and the screen chamber, and in the foundation slab, the caisson and the piers to the elevations given on the appropriate drawing. Class B includes the remainder of the concrete for the screen chamber and the concrete cover for the structural steel in the floor system and the box girders, and filling the box girders with 1 : 4 grout, and the precast slabs for the stop-log shafts.

Item 11 includes furnishing and placing additional grout piping through the concrete masonry, and all the grouting provided for in Items 7 to 10. Grout pipes are at least 1½ in. and of as short lengths as practicable. After grouting, all pipes are filled with mortar, the cast-iron plugs are screwed flush and the recesses in the concrete filled with mortar and smoothed.

Sealing Abandoned Intake Conduits—In the illustration are shown two abandoned brick gate-wells now filled with earth and other materials. One is located within the space to be occupied by the screen chamber, and the other a little to the east of this chamber. A 6-ft. intake conduit extends from the riverfront to the first gate-well and a 5-ft. conduit to the second well. These conduits continue from their respective gate-wells toward reservoir No. 1. These portions of the conduit and the first 45 ft. toward the river are built of three rings of brick, the remainder being either of riveted steel or wrought-iron pipe in lengths of 26½ ft. with stovepipe joints. Because of the location of the gate-wells and conduit with respect to the structures to be built under this contract, it is necessary to seal these conduits from the river and bulkhead and fill portions of them near the screen chamber.

Item 17 requires the contractor to (1) uncover the river end of the abandoned 5- and 6-ft. intake conduits and later refill the excavation; (2) dewater them; (3) build watertight bulkheads at the river ends; (4) fill between bulkheads a 45-ft. section of the 5-ft. conduit where it crosses over the 15½-in. tunnel and a 30-ft. section of the 6-ft. conduit adjacent to the screen chamber on the south side; (5) build a bulkhead in the 6-ft. conduit adjacent to the screen chamber on the north. This work is to be completed before starting sinking the screen chamber caisson. The bulkheads are of common brick masonry. They are 3 ft. thick and secured against moving under pressure from the river. The sections of conduit between bulkheads are to be filled with sand and clay and the voids are grouted. Payment is by lump sum.

Removing Masonry Bulkheads—Item 18 calls for (1) removing the bulkheads closing the opening in the shore shaft provided for connecting with the 15½-ft. tunnel; (2) the west bellmouth of the auxiliary low-lift plant; (3) the south end of Pennsylvania Ave. tunnel; (4) the openings in the screen chamber caisson for the 15½-ft. and 11-ft. tunnels. The bulkhead in the shore shaft is built of concrete 30 in. thick and reinforced with three 16-ft. 90-lb. beams; in the west bellmouth, of reinforced concrete 8 in. thick; in the south end of Pennsylvania Ave. of brick 3 ft. thick; and in the screen chamber caisson as shown on the appropriate drawings.

The river tunnel is now being driven from the shore shaft. In driving that portion of the 15½-ft. tunnel connecting with this shaft and in removing the bulkhead, the contractor will use every precaution to prevent injury to the forces in the river tunnel, and structural damages and delay. Payment is by lump sum.

Timber and Lumber—Item 19 is for No. 1 yellow pine or fir lumber used for support of excavations and left in place.

The Bidders—Five bids were received for the land tunnel and structures, four from Detroit firms and the successful bid from the Dravo Contracting Co., of Pittsburgh. The spread between low and second was 7 per cent, and between low and average 18 per cent. The tabulation gives the lowest two and the average of all prices. Contractor B is the J. A. Mercier Co. The other contractors were the George R. Cooke Co., S. A. Healy and the Mark R. Hanna Co. George H. Fenkell is general manager of the department of water supply.

	A	B	Average of All Bids
1 Shaft excavation, 3,300 cu.yd.	$12.00	$15.50	$16.00
2 Air-compressing plant and locks, lump sum	19,500.00	14,000.00	21,100.00
3 Tunnel excavation, 27,500 cu.yd.	5.20	5.75	6.39
4 Excavation for screen chamber, 8,200 cu.yd.	5.00	4.25	6.35
5 Timber left in tunnel, 20 M.ft.b.m.	120.00	30.00	80.00
6 Steel "timbering" left in tunnel, 20,000 lb.	0.09	0.06	0.102
7 Concrete shaft lining, 1,400 cu.yd.	14.50	17.50	19.80
8 Concrete tunnel lining, 11,200 cu.yd.	14.70	15.75	16.69
9 Concrete in structures class A, 2,900 cu.yd.	12.00	13.80	17.18
10 Concrete in structures class B, 700 cu.yd.	16.00	25.00	27.00
11 Grout, 1,200 bbl.	5.50	8.00	5.90
12 Cores from concrete, 36 cores	100.00	75.00	79.40
13 Reinforcing steel, 975,000 lb.	.05	.045	.054
14 Structural steel, 350,000 lb.	.055	.06	.0614
15 Timber piling, 8,000 lin.ft.	.50	.83	.966
16 Steel sheetpiling left in place, 180,000 lb.	.03	.055	.047
17 Sealing abandoned intake conduits, lump sum	6,000.00	7,000.00	5,449.20
18 Removing masonry bulkheads, lump sum	3,000.00	2,000.00	3,559.20
19 Timber and lumber, 6 M.ft.b.m.	120.00	30.00	84.00
20 Misc. iron and steel, 33,000 lb.	.09	.12	.142
21 Cleaning up, lump sum	5,000.00	7,000.00	6,545.60
Totals	$583,530	$632,200	$709,715